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COMING MEETINGS

Pacific Coast Convention, Seattle, Washington, September 15-17

MEETINGS OF OTHER SOCIETIES

American Society of Civil Engineers, Salt Lake City, July 8-10

N. E. L. A.—East Central Division, Breakers Hotel, Cedar Point, Ohio, July 14-17; North Central Division, Duluth, Minn., July 15-17; New England Division, Hotel Griswold, New London, Connecticut, Sept. 8-11; Rocky Mountain Division, Hotel Colorado, Glenwood Springs, Col., Sept. 14-17; Southeastern Geographic Division, Birmingham, Ala., Sept. 15-18; Great Lakes Geographic Division, French Lick Springs, Ind., Sept. 23-26

International Association of Municipal Electricians, Hotel Statler, Detroit, Aug. 17-20

Association of Electragists International, West Baden, Ind., Sept. 23-25

American Institute of Mining and Metallurgical Engineers, Salt Lake City, Utah, Aug. 31-Sept. 3

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Illinois Engineering Society Transactions, May 1925

Records of Daylight by the Photoelectric Cell, by J. E. Ives

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Roll Drives, by E. A. Hurme

Oak Grove High Head Turbine Development of the Portland Electric Power Company, by E. C. Hutchinson

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Distribution Costs of Power, by P. T. Davis (May 1925)

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OUR ANNUAL CONVENTION

THE FORTY-FIRST ANNUAL CONVENTION of our Institute is now a matter of history and can be recorded as a highly successful affair from every standpoint and marks a further step of progress toward the type of convention which seems particularly suited to the present needs of Institute work.

The better coordinated opinion of the Section delegates from all over the country indicates a clear understanding of the Institute's activities and aspirations, and one of the most important actions at the Delegates' Conference was the resolution endorsing regional meetings under the procedure as prescribed by the Board, after two years' trial with complete success, proving that the Institute is making no mistake in its plan for bringing out in a better and broader way the work of the whole membership. The report from nearly all delegates of cooperative local meetings with members of other societies shows that the Institute is trying to do its part in putting to use for the general good its technical experience and judgment.

The most noteworthy features of the Convention's technical program were two: First, there were no afternoon sessions, and while two evening sessions of much interest and importance were held, it was the general opinion that a respite from the continuous intense work of all-day technical sessions made for a clearer and livelier discussion at the sessions.

The second important feature was the matter of presentation of the annual reports of our technical committees, which were all so carefully prepared by the respective chairmen and were so intelligently abstracted as to permit of their prompt presentation, leaving plenty of time for full discussion. It will be remembered that at some of our meetings in the past the time for discussion has been limited to the point of undesirable curtailment, but it would seem that with the plan of this year has been found the most useful way to orient the far-reaching work of our technical group. The preparation of the reports, covering as they now do, the activities of the year in each of the special fields would seem to put before the members the whole history in the shortest way and provide the best basis for general discussion and comment. This was clearly demonstrated at one of the meetings when the reports had all been presented in about an hour and there was a three-hour discussion following the presentations. In order to be sure that this plan met with favor, an expression of opinion was formally asked of the members, which was favorable to this scheme of program, and which doubtless will be carried forward at later conventions perhaps to a not illogical point of making this work the major part of the technical program.

It was a great pleasure to see many more ladies than usual at the convention, and as our Institute folks increase their acquaintance, their attendance in larger numbers seems assured, which will add greatly to the personal side of our meetings.

To our Convention Committee especial thanks should be given for the admirable arrangement of the program, which was done with full cooperation with the Meetings and Papers Committee and the Board of Directors in order that we might give a fair trial to this rather new form of arrangement. Having afternoons free not only gave relief from a too long continuous period of attention to technical matters, but made it possible for many committees having a large proportion of their members present to hold meetings or conferences and accomplish a good deal of real work, due to the fact that on such an occasion the representatives from far sections of the country are on hand. The Convention Committee took the opportunity provided by the free afternoons to arrange a large number of delightful and instructive inspection trips and drives, and cared for all the athletic events in a way which made the whole meeting a healthy and delightful one.

As this is the closing of the administrative year, your President wishes to thank hereby the Chairman and members of each Institute Committee for their untiring work for the Institute good, and it is only with such unselfish loyalty that the Institute has attained its enviable position of today and will so go forward.

It has been a real personal pleasure to the President to have had the opportunity to meet so many of the Institute's members this year, which has seemed to bring us closer together in a clearer understanding of what our real work should be and how much we mean to each other, focussing always to our general headquarters where our good friend and excellent executive, National Secretary Hutchinson, and all the members of his staff care for our interests and keep us fully advised of our activities everywhere.

In thanking the whole membership for its cooperation, and particularly the Chairmen and members of the Institute's committees, your President retires in the hope that he has satisfactorily done his bit, yet no more than any other member, and welcomes most heartily with every wish for a better year, our distinguished President-elect, Dr. Pupin.

FARLEY OSGOOD

Some Leaders of the A. I. E. E.

Bion J. Arnold, the sixteenth president of the Institute, was born in Casnovia, Michigan, August 14, 1861. His early education was gained in the public schools of Ashland, Nebraska. later attending the University of Nebraska and Hillsdale (Michigan) College, from which he received the degree of B. S. in 1884 and M. S. in 1887. In 1888-89 he took a post-graduate course in electrical engineering at Cornell University.

Mr. Arnold received the honorary degree M. Ph. from Hillsdale College in 1889; E. E. from the University of Nebraska in 1897; Dr. Sc. from Armour Institute of Technology in 1907, and Dr. Eng. from the University of Nebraska in 1911.

After leaving Cornell University, Mr. Arnold was for four years associated with the Thomson, Houston Company, and its successor, the General Electric Company. A notable achievement of his during this period was the design and construction of the Intramural Railroad in the grounds of the World's Columbian Exposition, Chicago, 1892-93. This was the first electric elevated railroad and the first railroad employing a third rail as working conductor.

In 1893 Mr. Arnold opened a consulting engineering office in Chicago, and organized the Arnold Company. Under his direction have been designed and constructed many electric central stations, electric railways, railway car shops, and so forth.

In 1902 he made for the city of Chicago an exhaustive study and report of the entire traction system within its limits. His recommendations were largely adopted in the settlement effected between the city and the several companies by the passage of the 1907 ordinances in which he was named chief engineer of the work and chairman of the Board of Supervising Engineers, Chicago Traction. This Board was appointed to see that the terms of the ordinances were carried out, and he still serves as Chairman. From 1906 to 1916 he acted as chairman of all the other commissions which valued the street railway properties during that period. He has also made similar studies and valuations for practically all the large cities of the United States and Canada.

In 1916 he served as a member of the Chicago Traction and Subway Commission. In 1913 the Citizens' Railway Terminal Plan Committee commissioned him to make a study and complete report on steam railroad terminals. Principally as the result of this study, the Chicago Railway Terminal Commission was created by the City Council to coordinate the work of that body, the Chicago Plan Commission and the Citizens' Committee, and he served as a member from 1914 to 1921.

He was a member of the commission that planned the New York Central Terminal electrification, New York, and of the Erie Railroad Commission, which prepared plans for the electrification of part of the system, 1901-6. He designed and carried out the electrification of the Grand Trunk tunnel under the St. Clair River in 1909, and was a member of the Illinois Central and Delaware, Lackawanna and Western Electrification Commissions 1920-22.

During the World War he was a member of the Naval Consulting Board of the United States and in December 1917 was commissioned Lieutenant-Colonel in the Aviation Section, Signal Corps, U. S. Army. He took an active part in coordinating the production of airplanes and aerial torpedoes, and is now a Colonel in the Air Service Reserve Corps of the Army.

Mr. Arnold was a delegate to the International Electrical Congress, Paris, 1900, and first vice-president and chairman of the Executive Committee of the similar Congress held in St. Louis in 1904. He was president of the A. I. E. E. during the term 1903-04, and is a member of many engineering and scientific societies.

Notes on U. S. National Committee of the I. E. C.

At the meeting of the U. S. National Committee held on June 4th in the Engineering Societies Building, New York City, certain changes were made in the officers. The resignation of S. G. Rhodes from the offices of Secretary and Treasurer was accepted with regret by the committee and in electing successors to him, it was felt desirable to elect an individual to each office. F. V. Magalhaes of The New York Edison Company was elected to the office of Secretary and H. S. Osborne of the American Telephone & Telegraph Company was elected Treasurer.

At the meeting formal announcement was made that the American Society of Mechanical Engineers had joined the U. S. National Committee and named as its representatives: Dr. F. R. Low, Dr. W. F. Durand, Alternate—C. Harold Berry.

It was announced at the meeting that a definite invitation had been extended to the International Electrotechnical Commission to hold its next conference in the United States. There was, therefore, some general discussion of the place of the meeting and the arrangements that might be made. While no conclusion was reached, the President was authorized to appoint a small committee which would make the necessary preliminary decisions and appointments, this committee undoubtedly to be followed by the appointment of special committees for the various necessary functions in connection with the visit of the delegates from abroad, as well as for the technical sessions.

There was no detailed technical discussion of the results of The Hague Conference, but a brief preliminary report was presented by H. M. Hobart, reporter for the U. S. National Committee. Mr. Hobart's report will be followed by a more comprehensive one now in course of preparation. It was apparent, however, that the meetings at The Hague had been very harmonious and the results of the various conferences had been profitable indeed.

The Engineer and Civilization
President's Address
BY FARLEY OSGOOD

The Institute

IT seems fitting at this time to bring to your attention, very briefly, some of the outstanding results of the work of the membership of our Institute during the administrative year just closing.

I am sure most gratifying to all, is the increasing interest and activity in Institute affairs all over the country, the greater appreciation of the value of the Institute, professionally and practically, and finally the enjoyment of personal contact of scientists and engineers for the mutualization of thought toward the advancement of our art. These facts are clearly brought out in the statement of the number of meetings and attendance given in the Annual Report of your Board of Directors for the fiscal year ending April 30, 1925.

The work of our Standards Committee, which covers not only a revision of and additions to our Standards, but a rearrangement of their set-up, which will make for their much greater convenience for field use, is worthy of the greatest praise, as it required much untiring and unselfish effort of a very large group of men determined to accomplish what has been done this year.

Our Meetings and Papers Committee has so coordinated its work with that of the Districts that regional conventions are now established on such a sound footing as to have made it desirable to abolish the National Spring Convention as such, which recommendation of the committee was concurred in by the Board of Directors at its meeting on May 15, 1925.

The revising of the constitution to bring it into line with the present scope of the Institute's activities, and the fast growing nationally spread membership has been accomplished, as was also reported at the Annual Meeting on May 15th in New York when the large affirmative vote by letter ballot was recorded.

The many Technical Committees have been even more active than usual, and through the JOURNAL from time to time you have seen how well they have prepared the sessions of the conventions falling under their several responsibilities. Their following the electrical engineers into new fields of industry is particularly to be commended as it is bringing into our Institute many new groups, as members and authors, not previously interested in our possibilities. The detail of the constructive work of the committees will be recorded in the history of this convention, for it is now our practise to have their reports presented at this, the last and presumably the most widely representative convention of the administrative year, in order that their conclusions may be more far reaching in their orientation, and that through the discussion, views of members from the greatest number of sections of the Institute may be expressed.

The report of our auditors indicates a healthy financial condition, and that we have paid our way this year. The slight increase in income as provided by certain changes in our revised constitution, will be most welcome for the carrying forward in a broader way important activities as seen to be needed by the Board of Directors.

The excellent result from our Membership Committee is shown in the fact that on June 1, 1925 our list of members totalled 17,318—representing a very satisfactory continuous growth since the formation of the Institute.

The Reason

Now, the relation of these events concerning our activities and growth, which are not unlike those of our sister societies, should bring to our minds the thought that there must be a sound reason for it all.

There is a sound reason, and it is in the indisputable fact that the engineers have made the world what it is today; have brought to it industrial progress and economy; have given it the living comforts and, more than all, have shaped the very scheme of living of its inhabitants since civilization began.

History

The living in trees to escape the hazards of ground life, to the steel strengthened structure of many stories;

The dispatching of runners with messages, consuming days of time and covering moderate distances, to the instantaneous international transmission of intelligence and music by physical conductors and through the air;

The shaping of the business end of the club of the savage that the greatest destruction might be wrought on the head of an undesirable neighbor, to the sending through the air, accurately and speedily, tons of metal to a predetermined point;

The thought of the wheel bringing relief to transportation by hand or with manual carriers, with its evolution through all mechanical applications to the precision and delicacy of present day timepieces;

The employment of steam as a mechanical agent to the point of mass energy for manufacture and transportation;

The development of highways, construction of bridges, furnishing of water supply, that humanity may dwell where it pleases;

The harnessing of electrical energy for nearly every purpose of industrial and domestic life;

The use of natural resources from the obtaining of

Presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

raw materials from the earth to the practical application of water streams and storage, which for centuries have been idle in their help to man;

The understanding of many of the mysteries of chemistry with their application to industry, health and comfort; . . . . all seem long steps in our notion of periods of advance, but all find their foundation in science and engineering. No one can say that but for these, and the very many related achievements, would the progress of civilization, the groupings of the peoples of this world, their interests, their methods and comforts of living, be such as we now behold.

Although centuries have passed while our present scheme of life has been perfected, it is only very recently that the rapid strides of applied science and engineering have been accomplished. To note the fact that as late as 1852 was founded America's first national engineering association, that of the Civil Engineers, is sufficient to indicate the rapidity of development of the engineering arts. The founding of the American Society of Civil Engineers in 1852 was followed by that of the American Institute of Mining Engineers in 1873. Then came the American Society of Mechanical Engineers in 1880, and finally our own American Institute of Electrical Engineers in 1884.

The very many and rapidly increasing special fields of engineering endeavor seem to have been the reasons for the birth of these now so-called "Four Founder Societies." As each new field opened up, and its immediate development was hastened by necessity, there was not the realization of its possible and essential coordination with the work of those in distinct lines already established. Now, however, that there is a breathing time sufficient to review the situation as a whole, coordination is being established, as can be recognized in the forming of the American Engineering Standards Committee, the American Engineering Council, the Society for Promotion of Engineering Education, wherein the needs of all engineering may be comprehensively discussed.

The electrical engineers whose art has such universal application in all branches of engineering for nearly every industry and every domestic service, have had much to do in the bringing to one center all the arts of engineering. If for technical reasons this move toward general coordination has been started, it is all the more important for the presentation of a unified national opinion of America's engineers in matters pertaining to our own welfare, and that of the nation where the knowledge and training of technical men may be useful.

That engineers have brought all this about, by no means signifies that their responsibilities have ceased or even lessened, for in fact they have become all the greater; as through scientific knowledge and engineering experience, must not only the material side of life but its relation to human existence, go forward.

Engineers by training are taught to think straight, to seek the plain truth without bias, to deal with facts only, and to marshall them toward the goal of practical and beneficial accomplishment. Who, better than they, can turn the knowledge and experience which has brought us to our present state, to its application in the less technical activities of life with which it has such a close relationship.

The advancement of science and engineering for its own sake is not enough, in its control of the forces and materials of nature, for the organizing and directing of men, and all that this means in its broadest sense, becomes the obligation of engineers in order that the human race may be fully benefited.

No finer example of full accomplishment of this ideal could be cited than the life of the renowned French chemist, Louis Pasteur, an almost fanatical devotee to his science, yet never without the parallel thought of the benefit of his results to all living people.

Here in America today we have our distinguished Secretary of Commerce, the Honorable Herbert Hoover, an engineer of proven accomplishment, a worker for humanity, beloved by those European nations so much helped by him during the World War; now devoting his power of discernment of fact to practical application for the industry and comfort of the people of our whole Nation.

Engineers up to now have been all too prone to become so engrossed in their own technique as to give little or no heed to the development of life about them, or to have any thought that they are a part of that life and should give to it of their ability and experience and judgment, as other men do, who too have vital interests at stake from which some time must be taken for the good of all.

President George Fillmore Swain in his address to the Civil Engineers as far back as 1913, advocated a more human engineering, while our past President, Arthur W. Beresford in his address to us in 1921, warned against the belief by engineers that they can run successfully all the jobs in the world; but surely between these two ideas is a middle road to follow where engineers can and should help in matters concerning which they possess useful knowledge. President John Lyle Harrington in his address to the Mechanical Engineers in 1923, speaks very definitely on the subject, and I commend for your careful reading and reflection these three addresses mentioned, which so clearly point the way we should go, that from engineers the world may get the fullest measure it so rightfully demands, and the position of the engineer may be recognized as it so surely deserves.

Of course, just being an engineer does not qualify a man as an executive, nor as a legislator, for such work requires broad human vision, balanced perspective, ability to sense relationships and effects, all of which faculties would seem to have been more generously bestowed upon lawyers and business men generally than upon men of technical training. Is this, however, the

fact? Have not the technical men these facutlies, but have neglected to develop them by special education and experience so as to bring them sufficiently to a prominent place in their mental activities and desires?

Faculty for other than technical work must be present in the engineer if he is to be a worker in the broad fields of life, but having such aptitude, his very technical training should make him a more useful, more forceful worker than those non-technically trained.

If you reflect but for a moment, you will realize that many, in fact most of the problems of our people are basically engineering problems, if not strictly so technically as many really are, at least so generally, as they have to be solved by analysis, and the weighing in the balance what is found to be the logical and practical result if one plan is followed, with similar results of some other scheme under consideration. This method of analysis is peculiarly that of engineers who by training are well fitted to lend a hand.

In few places where the engineers could be helpful, do we see their names listed. To be sure here and there we find them, and how well these few perform their duty is a matter of record. The names of these men are mentioned with pride, but it is the exception rather than the general rule to find our members in such activities. In our principal body of national representation, our National Congress, how many names of engineers do we find? This body is composed largely of lawyers, over 65 per cent, and politicians whose business at home is not engineering. These are the men who pass on the problems of the country so many of which, as we have endeavored to show, are such as could be more logically determined by our technical men.

Truly, by now we have come to the time when our experience must be turned to broader fields of investigation than those confined to our technique; and how is this to be brought about?

A new state of mind in the engineer must be born. Those most advanced in our art must appreciate their debt of service to the needs of the people not having our training in the determination of facts; our educators must be brought to appreciate that the training of young men in the technique of their work, is but a part of the training for a suitable graduating degree. Our college students must be made to realize that their particular training incurs an obligation of its service for the benefit of all our people, wherever it is possible to bring it to bear.

In so many of our commissions and political bodies we find the make-up largely lawyers, with a few other non-technical men, whose work deals primarily with projects based on engineering, and as a consequence many engineering experts are called to bring in the scientific and technical facts that proper decisions may be reached.

Why, now that the legal and financial bases of most of the investigations by our public bodies have been so well established, should not the personnel consist largely of qualified engineers, and when legal or financial advice is needed, call in the experts from those fields? Would not this seem more logical? Has the training of our scientists and engineers been such as to make them unfit for this duty? If so, it is high time that intensive study should be undertaken to correct such a condition.

It would seem reasonable for a well balanced committee of the four founder engineering societies to be formed, selected from many branches of industry and the world work to cooperate with the Society for the Promotion of Engineering Education, in order to determine most broadly on a proper curriculum for our students, to bring to them a correct blending of technical work and training in human engineering; that our profession may perform its fair share of carrying on the welfare of our people.

Even if much which is now taught is abolished from our present curricula, and the fundamentals of the technique of our art made more thoroughly understood, with training in expression of their application, both orally and in forensic, so as to be clearly understood by non-technical men of the business world, a much broader viewpoint of the engineer, and a much wider appreciation of what he can do in the world's affairs will result.

No longer should we be looked upon as "glorified mechanics," when in our combined mentality and our essential training in the discernment and arrangement of facts, exists such a potentiality for helpfulness to all mankind. If we so continue we can have only ourselves to blame, and now that we have come so far, what a shame to rest in a feeling of complacent satisfaction.

Of course every engineer in the country cannot be placed in public office, either municipal, state or federal, but all engineers can lend aid in supporting those chosen for the more conspicuous places. Each has his own field of usefulness, by training or by choice, and his feeling of reward should be his satisfaction of service rendered.

The Master Mind of all creation holds the key of all knowledge; to the scientists is entrusted the unfolding of the fundamental laws of nature, to the engineers their practical application for the benefit of the human race in every possible way; the road is open, our duty is clearly defined, that our obligations will be fulfilled there is no doubt.

CENSUS OF LIGHTING EQUIPMENT, 1924

The Department of Commerce announces that, according to returns received at the annual census of manufacturers of lighting equipment, the total value of such equipment made during 1924 was $205,866,358, an increase of 13.8 per cent as compared with $180,926,000 in 1923. Reports were received from 720 establishments for 1924, as compared with 732 for the preceding year.

The Trenton Channel Plant
of the Detroit Edison Company

BY C. F. HIRSHFELD[1]
Associate, A. I. E. E.

Synopsis.—*This plant is the second to be built by this Company well outside the corporate limits of Detroit, the two being connected by a 120-kv. tower line arranged for supplying suburban areas and the outer part of the city. The plant has a planned ultimate capacity of 300,000 kw. It contains both d-c. and a-c. house service, turbine-driven units and nearly all important variable speed auxiliaries are driven by d-c. motors. Coal is used in pulverized form, the paper giving the conclusions which led to its adoption.*

THE Trenton Channel Plant is one of several interconnected plants serving Detroit and surrounding territory. Its location and many of its characteristics are determined by this fact and a brief statement of some of the characteristics of the territory and system is therefore desirable.

Detroit is located on the Detroit River and has a roughly semicircular shape with the river bank serving as the diameter. This can be seen in Fig. 1, in which the territory served by The Detroit Edison Company is indicated. It will be seen that the City of Detroit is on what might be called one edge of this area.

Steam plants generating power for the supply of Detroit and surrounding territory must logically be located on the water front provided by the Great Lakes System since no rivers in this region are large enough to supply the circulating water requirements of stations of modern size. This brings about a situation in which the power is necessarily generated along the easterly boundary of the area, that is externally, except in so far as a few small hydroelectric plants located on the Huron River give what might be called an internal supply.

The first two large steam plants of the company are located within the city boundaries and are known respectively as the Delray and the Connors Creek Stations. The power generated by these stations is carried out underground and most of it at 23,000 volts. The territory external to Detroit was thus necessarily supplied by lines radiating from Detroit and fed by the underground system.

This arrangement came about quite naturally and was quite satisfactory for some years. However, as the density of load in Detroit and in the surrounding territory increased it brought about several very illogical, undesirable and costly consequences. The most obvious were:

1. Power generated in plants located on costly land within the city and subject to high city taxes was transmitted over costly underground structure, also subject to city taxes, for the purpose of supplying overhead transmission lines serving small suburban towns and cities and country areas.

2. The power required for service to the least saturated territory had to be passed through the most nearly saturated territory thus unnaturally increasing the difficulties brought about by congested streets, high property values and the like.

3. The point of power generation was located some distance from a few of the larger suburban loads, as at Pontiac and Port Huron, making regulation difficult or exceedingly complicated and costly.

4. The coal supply for these plants comes in by rail from the South and must be handled through congested city yards and over congested terminal railroads while much of the power generated from this coal was again shipped out of the congested territory.

In addition to these obvious disadvantages it became evident that the total capacity of the combined plants would shortly be required to supply the city alone and that it would not be long before even that capacity would be inadequate for the city's needs. The natural thing to do was to locate future plants outside the city and in such positions as to be of maximum value to both the surrounding territory and the municipal area.

The first of these newer plants was constructed at Marysville near Port Huron. This location was near one end of one of the longest transmission lines and very close to one of the largest concentrated loads outside the city of Detroit. The second of these plants was built almost at the other end of the available water front, namely, just below the city of Trenton and is known as the Trenton Channel Plant.

This location is such that the coal carrying roads run close to the plant on their way to Detroit, so that coal can be delivered to the plant without having to enter the congested Detroit district. The location also has the advantage of placing the plant in a section of the territory which is rapidly developing to a dense industrial district and all indications point to this section as the one which will continue to develop most rapidly in this way. Other advantages of the location will become apparent from subsequent paragraphs. The locations of the two older and the two newer plants are indicated on Fig. 1 and the air-line distances between them are also given.

With these two new plants in existence an entirely different system of transmitting energy becomes available. A 120,000-volt line which might be de-

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[1]Chief Research Dept., The Detroit Edison Co.

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scribed as a trunk has been run between them and it has been given such a course that it swings out into the country areas to the north and west of Detroit. The location of this trunk is shown on Fig. 2 by a heavy line. The lighter lines indicate existing 23,000- and 45,000-volt lines which originally transmitted energy from the Detroit plants.

These lines will ultimately be fed from step-down stations located along the high-tension line and some of them will not only supply the smaller towns and country

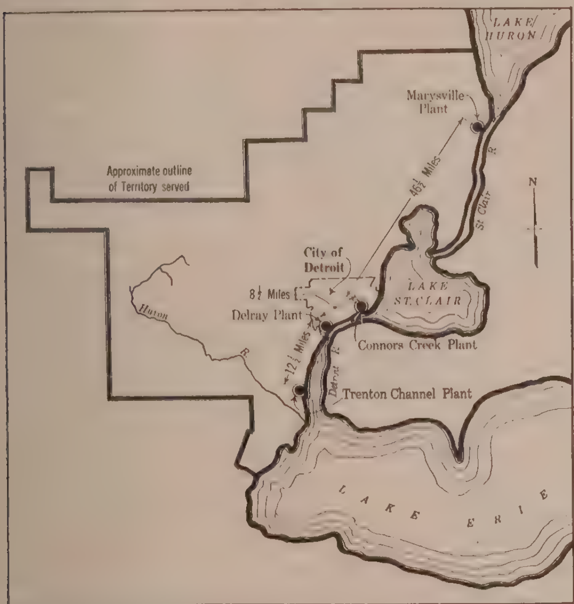

Fig. 1—Territory Served by the Detroit Edison Company

areas but will also feed back into Detroit. This gives a more logical arrangement since large amounts of energy can be brought in through the least congested areas to feed the most congested.

It will be seen in Fig. 2 that the high-tension trunk runs through a place named Brownstown near Trenton Channel and also that high tension lines run roughly north and south from Brownstown. Power generated at Trenton Channel is transmitted to a switching station at Brownstown and is there routed over such circuits of the three radiating lines as may be desired. In addition, some of the power received at Brownstown is there stepped down to 23,000 volts and distributed for the supply of adjacent territory. Power routed to the north is used to supply the industrial area southwest of Detroit and also to supply the west side of Detroit, thus partly relieving the old Delray Station. Power routed to the south now supplies a rather large load in Monroe at the extreme southern end of the territory and will ultimately also supply a heavy industrial development which is expected to follow down along the water front. Power routed to the west supplies the country areas and suburban municipalities and some of it will ultimately be fed back into the northern part of Detroit.

When the lines running out from Trenton Channel are completed there will be three steel-tower lines, each carrying two three-phase circuits of No. 3/0 copper, thus giving six circuits or transmission lines. Four of these will run direct to Brownstown and two will run to one of the outdoor stations lying on the western edge of Detroit. Connections between this station and another of similar character will serve to tie this line from Trenton Channel to the short line running north from Brownstown when desired, thus giving a looped supply to these two important substations.

Arrangements have been made at Trenton Channel to step up to voltages lying between 110,000 as a lower limit and 120,000 as an upper limit. Arrangements are being made for two separate high-tension busses. It is obvious that when completed this will make it possible to supply the loop just referred to at a low voltage and still use the higher voltage on the trunk line if this is required to meet existing conditions of load.

The use of two separate busses also makes it possible to continue and extend a practise which has been a striking characteristic of the operating methods of the company for several years. This practise may be described as a loose linkage or a limited linkage between generating units, using the latter term to mean a group

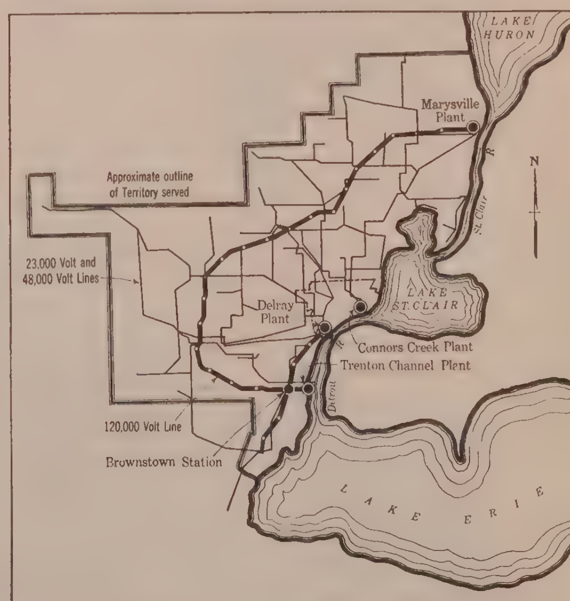

Fig. 2—Transmission Lines of the Detroit Edison Company

of turbo generators such as a large section of a single generating plant or an entire plant. The practise was started by dividing up the territory in such a way that each plant supplied the area nearest to it and then connecting the separate areas by the minimum possible amount of copper. As a result, all plants remained in step under normal conditions and even under slightly abnormal conditions such as the loss of a generator at one of the plants. However, a serious fault such as a

bad ground would create sufficient disturbance to break the areas apart, thus confining any subsequent trouble to the affected area. This practise was brought about by an effort to reduce the severity of the service on oil switches.

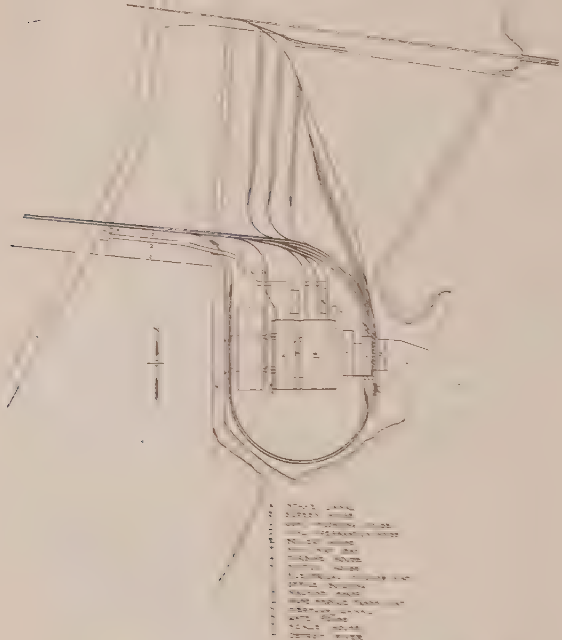

Fig. 3—Ground Plan, Trenton Channel Plant and Yard

The Trenton Channel Plant is located on the southern end of an island in the Detroit River. This island is known as Slocums Island and is or was merely a piece of high ground separated from the high mainland by a narrow marsh. A channel has been dredged through this marsh so that the so called island is now an island in fact. The plant site is underlain with a good grade of limestone rock at a depth of about 18 to 20 feet beneath the original surface of the ground so that ideal foundation conditions exist.

The plant is so located on the site that its major axes run approximately north and south and the flow of circulating water through it is approximately from the east toward the west. This water is taken from the Trenton Channel of the Detroit River on the east of the island and is discharged into the dredged channel to the west previously referred to. The general location and arrangement are shown in Figs. 3 and 4.

Starting at the river, the circulating water enters a forebay protected by deflecting piers, booms and skimming aprons and flows through the screen house on its way to the intake tunnel under the turbine house. The usual arrangement of inclined traveling screens protected by stationary rough screens or grizzlies is used.

Next to the screen house is located the coal unloading house. This contains two through tracks located above track hoppers into which the coal is dropped from gondola type cars. Crane rails, supported on the building columns in the usual way, carry a coal spudding device similar to those used for breaking up and unloading coal in the other plants of this company.

All coal entering the plant or going into storage is

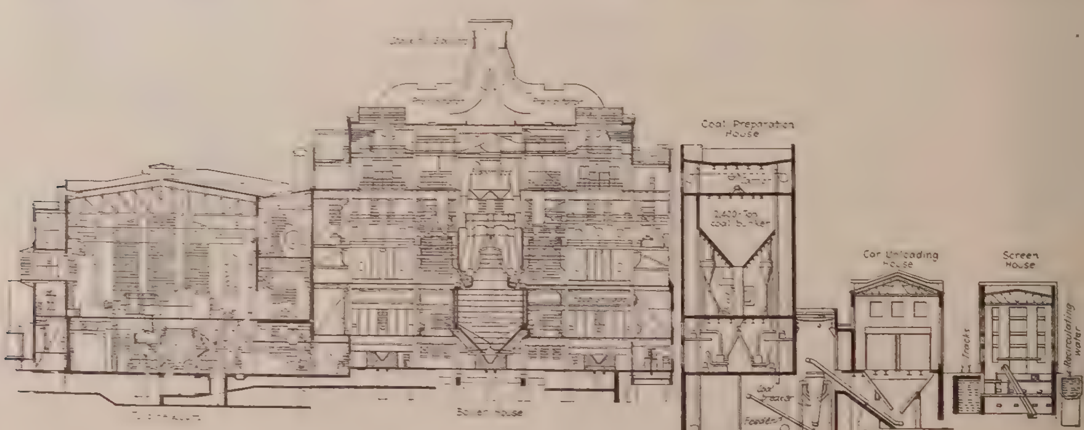

Fig. 4—Cross Section, Trenton Channel Plant

The same practise was adopted with respect to the individual plant. When conditions are sufficiently severe the plant bus is split and the feeders and networks so handled that there is minimum possibility of a serious fault on one part of the bus affecting service from the other part. It will be seen that the double bus arrangement provided at Trenton Channel fits into this method of operating.

weighed on railroad track scales located on a track which runs between the screen house and the unloading house. These scales are indicated in Fig. 3.

Coal dropped into the track hoppers is carried away and elevated by means of pan conveyers which discharge it into the feed end of a Bradford breaker. This arrangement together with subsequent coal handling equipment is shown in Fig. 5. From the breaker

the coal is elevated to the green coal bunker at the top of the coal preparation house. From there it gravitates through steam heated, air circulating driers into the pulverizing mills. The pulverized fuel is carried out of the mills by air, separated from the air in Cyclone separators and delivered from these by screw conveyers to the hoppers of Fuller-Kinyon pumps. These pumps are coupled to a duplicate piping system which distributes the pulverized fuel to the bunkers in the boiler house.

Pulverized fuel firing was chosen for this plant after elaborate studies which were based on the best attainable data. It was realized that recent developments in stokers combined with the meagreness of information regarding actual operating costs with pulverized fuel made a study of this kind exceedingly difficult and tended to throw doubt on the correctness of the conclusions. However, the following conclusions seemed to be justified:

1. The pulverized fuel method had been developed to such an extent that continuity of service approximately equal to that obtained with stoker firing could be expected.

2. The total cost of steam, including all operating and capital charges, would probably not be any higher with the pulverized fuel method than with stokers and possibly a little lower when using the same number of boilers with either method of firing.

3. It appeared that it would be possible to obtain a flatter efficiency curve over a wide range with pulverized fuel than with stokers and to obtain high boiler ratings with greater facility, thus making it possible to use a smaller number of boilers advantageously and to reduce capital charges by a corresponding amount.

4. It seemed certain that a pulverized fuel plant would be less dependent on the supply of a particular quality of coal. This is not intended to mean that it was expected that such a plant could burn all sorts of coal with equal facility but that such variations as must naturally be expected to occur in the deliveries from a given field would not have as great an effect upon capacity and efficiency as had proved to be the case with the older, stoker fired plants. It was also hoped that poorer grades of coal than had been found best suited for stokers of the type previously used might be found to give commercially satisfactory results, thus increasing the flexibility of coal purchasing in several respects.

The decision in favor of pulverized fuel was based very largely upon the fourth conclusion, namely greater flexibility with respect to character of coal. This was particularly important in this case because the plant is so located that cars of poor or questionable coal can easily be dropped there before entry to Detroit. It is thus possible to skim off the best coal, figuratively speaking, for delivery to the Detroit plants and to drop the poorer varieties on the way into the city.

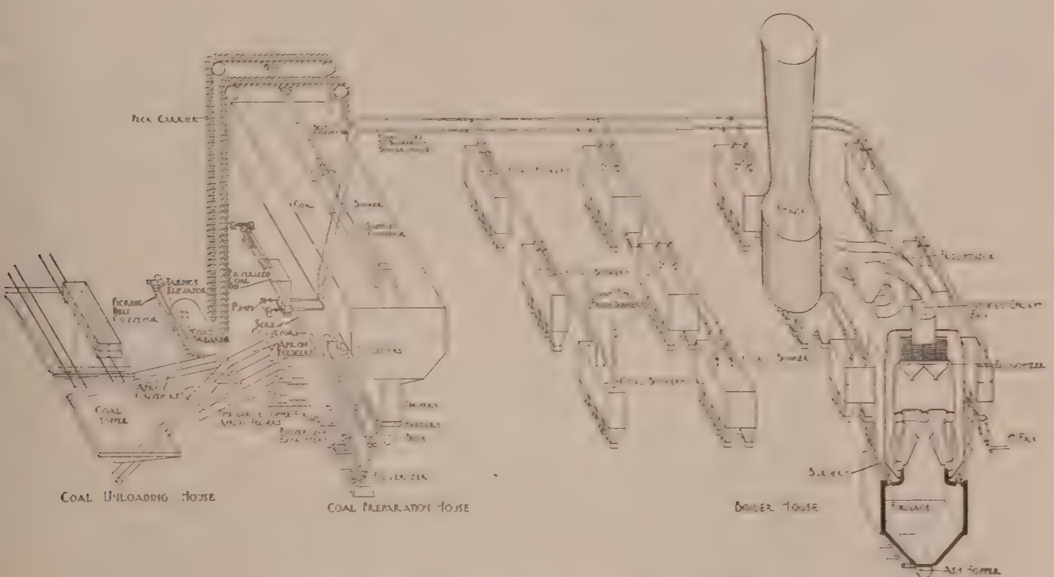

FIG. 5—COAL HANDLING PREPARATION, AND FIRING EQUIPMENT

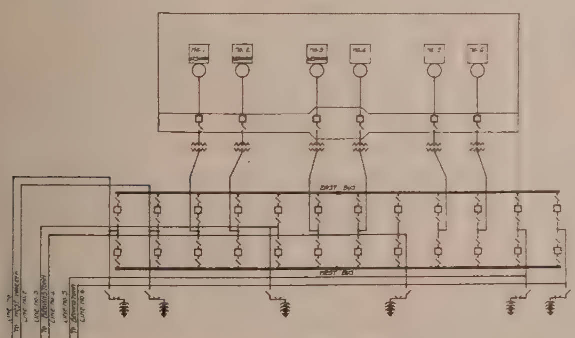

FIG. 6—ULTIMATE ARRANGEMENT OF BUSSES AND LINES

The plant was laid out for an ultimate installed generating capacity of 300,000 kw. The design is based on the use of six 50,000-kw. units. Three have been installed and the fourth will be installed in the near future.

The generators of these units are rated at 62,500 kv-a. at generator voltage corresponding to 120,000 volts on the transmission line. The nominal generator voltage is 12,200. The turbines are designed for best efficiency at a generator output near 43,000 kw. with steam at 370 lb. and 700 deg. fahr., but can carry something over 50,000 kw. at reduced efficiency. Under ordinary conditions the generators will be operated well below their maximum capacity and therefore at low temperatures which should result in long life of insulation. The field circuit has been designed very liberally and the direct-connected exciter is generously large so that occasional operation with high current, as with poor power factor or maximum output at low voltage, is provided for. Great flexibility is thus obtained with respect to generating conditions and full advantage may be taken of the double bus already described and the variation of voltage desirable in feeding from the same plant concentrated loads at short distances and scattered loads at great distances.

Each generator is tied solid to a 25,000-volt, 4000-ampere oil switch which is located in a bay which runs along one side of the turbine room. Beyond this oil switch there is located a disconnecting switch and then the line runs outdoors to the step-up transformers. There are three water-cooled, outdoor-type transformers per generator and they step up through delta-Y connections to bus voltage, that is, to a value between 110,000 and 120,000 as desired. The transformer ratio is fixed, the variation of voltage being obtained at the generators.

The step up transformers are connected to the outdoor busses through 132,000-volt, 400-ampere, outdoor-type oil circuit breakers with the usual disconnecting switches.

Thus, each generator with its own set of transformers and its switches is a separate unit right up to the high-tension, or transmission line bus. The lower-voltage, indoor switch is used for normal operations such as connecting a generator to the bus after synchronizing. Both the indoor and the outdoor switches, however, are automatic under relay operation.

The neutral point of each generator and the neutral point of each step up transformer Y is connected solidly to ground. Differential relay protection is provided for each generator and bank of step up transformers as a unit and differential and overload relay protection is provided on out-going lines, the pairs of lines normally being operated in parallel.

A single line diagram of generator connections, outdoor yard and out-going lines is shown in Fig. 6 in the form which will be assumed when the plant is completed. A cross-section of the electrical end of the house and the outdoor yard is shown in Fig. 7.

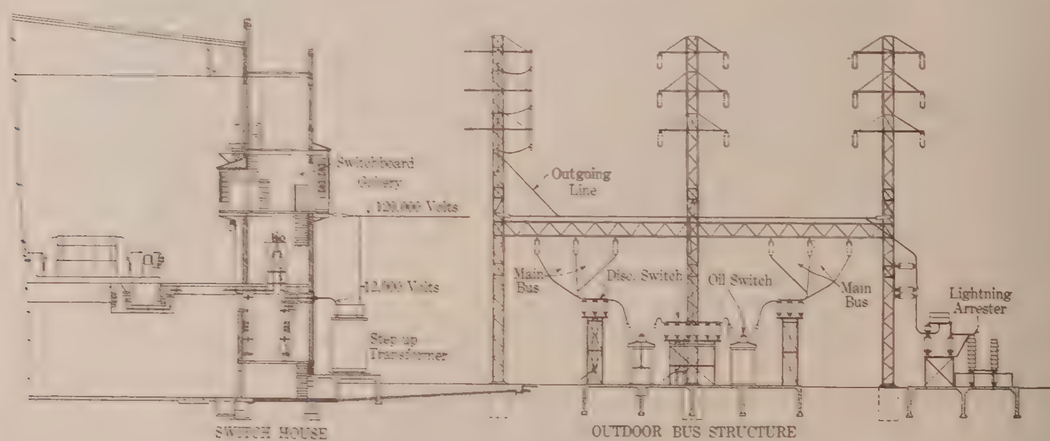

Fig. 7—Arrangement of Electrical End of Plant

The uncertainty with respect to what limitations might be discovered in the use of pulverized fuel dictated a rather generous design of boiler room. It seemed probable that eighteen boilers of the size chosen should be sufficient for a 300,000-kilowatt station but the design was so arranged that three more could be added if necessary. To date operation has indicated that eighteen will certainly be sufficient and it is possible that a still smaller number will prove satisfactory.

The boilers chosen are a double ended, five drum, curved tube type similar to those used in the older plants of the company. They have, however, been redesigned in the light of experience and tests, with the result that greater capacity is obtained within a given floor area and height with an increase in the boiler efficiency. The boilers installed contain about 29,000 sq. ft. of saturated surface designed for an opera-

ting pressure of 416 lb. per sq. in. Hearth screens add about 1200 ft. of saturated surface. The superheaters give a steam temperature of about 700 deg. fahr. Each boiler is surmounted by two steel tube economizers built into a single housing, the gases flowing from the dampers through flues and economizers toward the center of width of the economizers and thence through induced draft fans to the stacks.

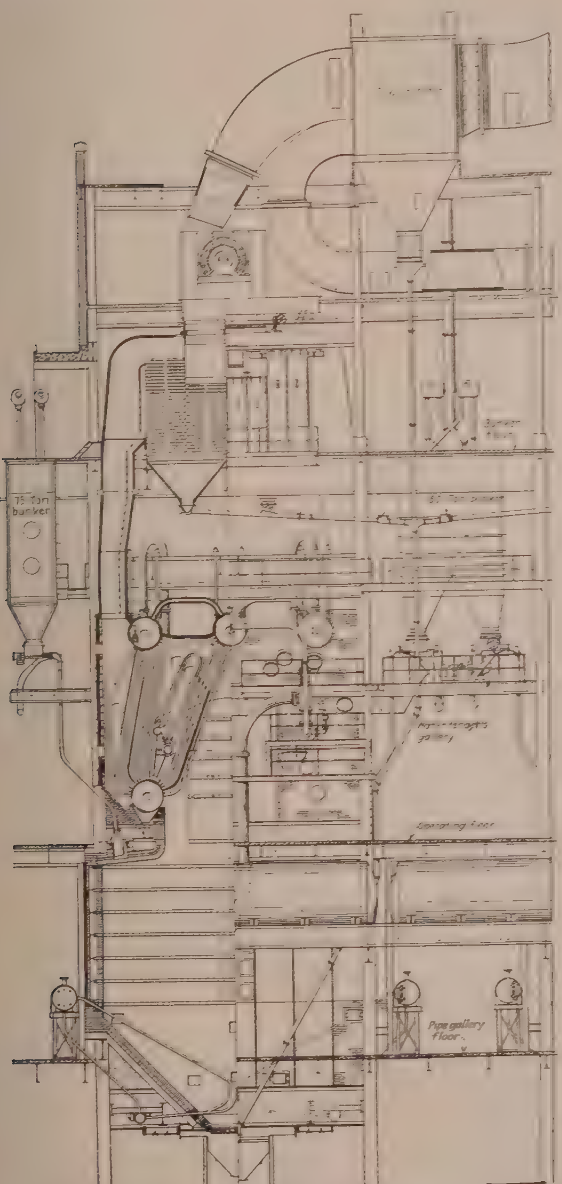

Fig. 8—Elevation and Part Section, One Complete Boiler Unit

A vertical, cross section of a complete boiler and furnace unit is shown in Fig. 4 and to a larger scale in Fig. 8. It will be observed that the furnace is of the common air-cooled type and that it is fired from two sides. The ash which collects in the furnace and that which collects in boiler and economizer is all dropped into a sluiceway under the boiler and carried to a settling basin outside the plant. At the present time this material is being used for fill on the property, being transported by means of a dredge pump and moveable pipes.

The Trenton Channel Plant happens to be located within a very short distance of a fine residential community. For this reason it was felt that it would be desirable to determine early in the life of the plant the best means of preventing excessive discharge of ash from the stacks. At the time that the plant was designed the Cottrel precipitator appeared to be the only commercially available device which had been used extensively for separating fine dust from hot gases and such precipitators were therefore installed on two stacks serving six boilers for the purpose of obtaining actual operating experience with them under power plant conditions. The limitations set by dimensions and by cost resulted in the purchase of precipitators intended to remove not much more than 90 per cent of the dust carried toward the stack. Experience to date is not sufficient to justify the drawing of sweeping conclusions but seems to indicate that it is possible by these means to eliminate from 80 to over 90 per cent of the dust without incurring prohibitive capital or operating charges.

The Trenton Channel Plant operates on what is commonly known as the regenerative cycle. That is, the main unit is bled at several points and the steam thus obtained is used for heating that unit's condensate in a series of closed heaters. However, the system as used in this plant is complicated by the use of certain auxiliary generators and other distinctive features and some of these should logically be considered before taking up the flow of steam and of condensate.

The experience of the company which built, owns and operates this plant leads it to believe that auxiliary energy supply should be reasonably independent of the main station bus, that is of the main generators. This is particularly true with respect to the supply for what are commonly known as essential auxiliaries. This experience also leads the engineers of this company to believe that when all things are considered the most satisfactory results are obtained when variable speed auxiliaries are driven by direct-current motors.

A supply of auxiliary energy independent of the main generators of the plant could have been obtained by feed back from the other stations of the company, by the use of auxiliary generators coupled to the shafts of the main units or by the use of independent, steam-driven, house-service generators. The first of these possibilities was eliminated except as will be noted later because of the distance from other stations, the possibility of having to operate the plant isolated from the others at times, and the complications and costs involved in bringing power back from outside in such a way as to make the auxiliary system independent of the

voltage variations planned for the station busses and the outgoing lines.

The use of direct-coupled, house-service units was given serious consideration. It has the great advantages of simplicity and low cost but certain undesirable features when applied to this particular plant. The desire to use both alternating and direct-current auxiliary supply and at the same time to make the auxiliary energy supply independent of other plants would have involved the use of alternating-current house service machines together with converting equipment for direct-current supply. Further, the starting of a single generator with its main auxiliaries driven by direct-current motors would have been practically impossible without an initial supply of energy from an external source. When all of the possible solutions along this line were considered it was felt that the third possibility represented the best solution in this case.

The station as finally constructed may be said to contain three different sets of generating units or to consist of three different generating stations. When completed the six main generating units will constitute one set; eight or ten direct-current generators driven in pairs through gearing by condensing steam turbines will constitute another set; and three or four 2300-volt alternators driven by condensing steam turbines will constitute the third set.

The direct-current units are 2000-kw., 250-volt machines with two armatures mounted side by side on a single shaft which is driven at 360 rev. per min. The turbine driving this double unit with a total capacity of 4000 kw. is a cross-compound affair with the high-pressure unit operating at 4000 rev. per min. and the low-pressure unit at 3000 rev. per min. These turbines drive the generators through pinions on opposite sides of a single large gear, the generator shaft being coupled to the shaft of this gear.

These turbines are arranged for bleeding at a pressure of about 10 lb., gage. The bled steam is used for building heating and for coal drying.

The steam which passes through these turbines is condensed in small surface condensers suspended beneath the individual turbines and each equipped with its own circulating pump, air pump and condensate pump. The condensate is delivered into the main feed water system as will be described later.

The alternating-current auxiliary units are rated at 2000 kw. each at 2300 volts. They are direct-connected to single barrel, condensing steam turbines which are arranged for bleeding but are not bled at present. The condensing equipment is similar to that just described and the condensate also enters the main feed water system.

A list of motor-driven auxiliary equipment with certain important data such as type of motor, speed, etc., is given in Table I. It will be observed that practically all motor-driven equipment in the boiler house is equipped with adjustable-speed, direct-current

TABLE I MOTOR SCHEDULE

Motors for	No.	H.P.	Voltage	Type	Rev. per Min.
	A-C. Motors				
Ash removal pumps	3	60	2200	Squirrel Cage	1200
Fuller-Kinyon coal pumps	3	60	2200	Squirrel Cage	1200
Pulverizer mill exhausters	14	60	2200	Squirrel Cage	1200
Aux. Air compressor, general service	1	60	2200	Squirrel Cage	1200
North and south long apron coal conveyor	2	25	2200	Slip Ring	600–1200
North and south short apron coal conveyor	2	25	2200	Slip Ring	1200
East and west pulverized coal screw conveyor	4	25	2200	Slip Ring	600–1200
South, middle, raw coal bucket conveyor	2	25	2200	Squirrel Cage	900
Coal breaker	1	150	2200	Slip Ring	520–720
Belt and shuttle coal conveyor	2	10	230	Slip Ring	900
Coal pulverizer mills	14	100	2200	Squirrel Cage	450
Picking belt conveyor	1	7½	220	Slip Ring	750–1200
2000-kw. house alternator circulating pump	2	60	220	Slip Ring	720–450
2000-kw. house alternator hot well pump	2	15	230	Squirrel Cage	1800
Air compressor for coal transportation	1	185	2200	Synchronous	225
Main air compressor, general service	1	185	2200	Synchronous	225
Crane over coal breaker	2	30 Total	220	Slip Ring	620
Screen house general service pump	1	240	2200	Squirrel Cage	1700
Coal unloader	6	20	230	Slip Ring	900
2000-kw. house alternator vacuum pump	2	25	220	Squirrel Cage	1800
Coal dryer	1	25	2200	Slip Ring	600–1200
Fan for crusher and breaker	1	25	220	Slip Ring	600–1200
	D-C. Motors				
4000 kw. d-c. house service turbo-generator hot well pump	3	25	240	Compound	1200–1600
Primary feeder blowers for boilers	16	30	240	Compound	1200–1600
Boiler coal feeders	64	2	240	Shunt	300–1200
Boiler damper	8	½	230	Series	575
50,000-kw. turbo-generator main circulating pumps	6	325/74	240	Shunt	255–175
General service pumps	2	175/240	240	Compound	1200–1700
50,000-kw. turbo-generator main dry vacuum pumps	3	66/14	240	Shunt	120–60
4000-kw. house service d-c. turbo-generator auxiliary dry vacuum pumps	3	25/12	240	Shunt	125–60
4000-kw. house service d-c. turbo-generator auxiliary circulating pump	3	60/37	240	Shunt	435–215
Boiler induced draft fans	8	350/12	240	Shunt	500–166
125- and 25-ton turbine room crane	4	170 total	230	Compound	725–800
Crane over Turbo-generators	3	47½ total	240	Compound	700–800
Blower for ventilating d-c. house service generators	3	20	240	Compound	460
Turbineroom exhaustfan	2	25/8	230	Shunt	1150–800
East roof ventilation fan	1	10/2.5	230	Shunt	420–290
West roof and window ventilation fan	1	15/4.5	230	Shunt	300–230
North window ventilating fan	1	10/2	230	Shunt	600–440
Hot drip return pump	2	25	230	Compound	1750
Boiler feed and hot well pump	3	700/400	240	Compound	1200–1000

motors and that the larger turbine house auxiliaries are similarly fitted. On the other hand, certain pieces of equipment located in the coal handling and coal preparation buildings and which require adjustable-speed motors are equipped with alternating-current drive. This was done because of the practical impossibility of preventing the generation and settling of coal dust in such places. It was felt that the greater freedom from danger of sparking together with the lower maintenance cost to be expected under such conditions of operation justified the use of adjustable-speed, alternating-current motors for such service. Constant speed motors are of the alternating-current type throughout.

operate a 500-kw. motor-generator set to supply the necessary direct current for starting a boiler in addition to operating such alternating-current motors as must be used during the starting up of the plant from cold.

The arrangement of auxiliary busses together with sources of supply and driven equipment is shown in Fig. 9. The direct-current bus is operated throughout at a nominal 240 volts and takes the form of several rings so arranged as to give maximum assurance of continuity of service. Structurally, this bus consists of copper bars supported by steel frames hung from the ceiling, the copper being insulated from the frame by blocks of alberene stone which are notched to receive the bars and are shaped to fit properly in clamps which

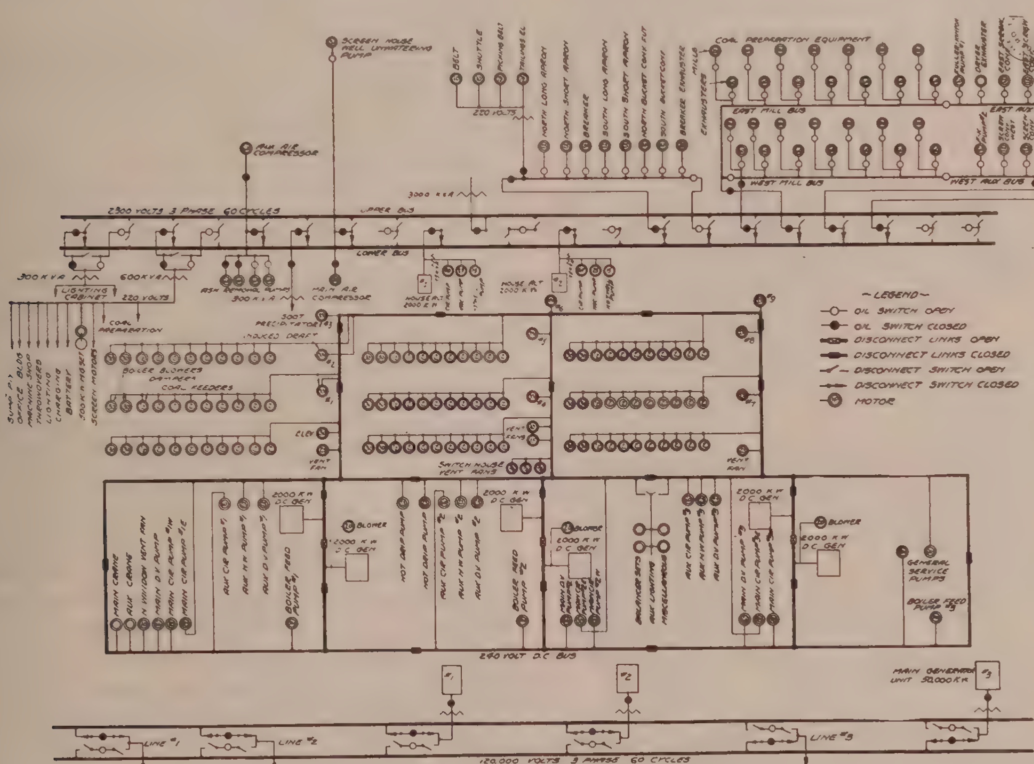

Fig. 9—Line Diagram of Auxiliary Power Supply

Consideration of the means for supplying auxiliary energy thus far described will indicate that the plant could not be started conveniently from a cold condition as electrical energy is required to operate the mechanisms used in supplying fuel to the boiler furnaces. For this reason and also as a matter of greater convenience and greater flexibility there is a feedback of 23,000-volt alternating current from Brownstown. This supply is stepped down through a 3000 kv-a. transformer and may be connected to the 2300-volt alternating-current bus. Ultimately this feedback connection will merely be a tap on the 23,000-volt distribution system in this territory.

This supply from outside the plant can be used to

are attached to the steel frames. These busses are protected by being wrapped with a double layer of canvas sewed in place with pressboard inside the canvas and above and below the copper. When the canvas is in place it is given several coats of bitumastic paint. This protection prevents trouble from accidental contacts and also serves as a water proofing.

The alternating-current bus is merely a duplicate bus of conventional type operating at 2300 volts. Throw-over switches for the larger motors or groups of motors together with provisions for connecting the two busses together give ample flexibility.

The plant and yard lighting is carried on the 2300-volt bus as shown at the extreme left hand end of Fig. 9.

Certain emergency lights throughout the power plant buildings have an automatic throw-over to the battery. Special outlets are provided throughout the plant for extension-cord lights at 28 volts alternating current. The use of such low voltage for extension cord work has been common in the plants of this company for many years and has been found exceedingly desirable because of the safety against severe shock. The lamp used for extension cords is the standard railroad coach light and is exceptionally rugged.

Returning now to the feed water circuit, it has been stated above that this is arranged for regenerative heating. A diagrammatic representation of the entire system is shown in Fig. 10. The normal water circuit may be traced by starting at the hot well of the main condenser in the lower left hand corner of the illustration. Water flows through the lower line from the hot well to the motor-driven condensate pump and then rises vertically to the 19th stage heater. It flows

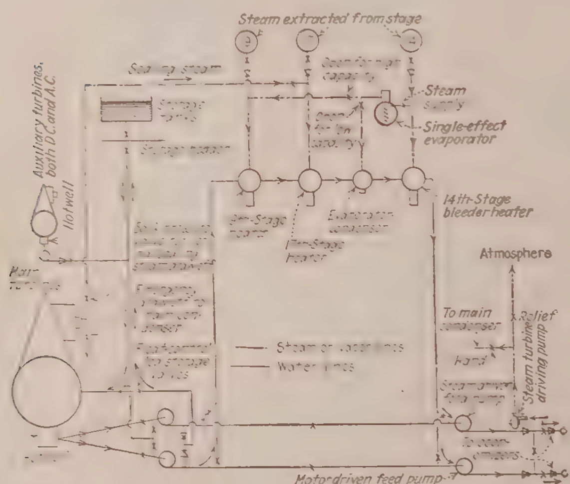

FIG. 10—DIAGRAMMATIC REPRESENTATION OF CONDENSATE SYSTEM

successively through the 19th and 17th stage heaters, the evaporator vapor condenser and the 14th stage heater and then vertically downward to the suction of the motor-driven boiler feed pump. This pump forwards it to the feed water headers from which the water flows through the various economizers to the feed drums of the boilers. The lower horizontal line in the diagram represents a bypass around all feed water heaters which makes it possible to pass water direct from the discharge of the hotwell pump to the suction of the boiler feed pump.

The motor driven hotwell pump and the motor driven boiler feed pump are coupled together and driven by the same motor. They are shown separated in Fig. 10 merely as a convenience in drawing the lines of flow. In effect these two pumps are equivalent to a single, multistage pump with provision for taking the water out of the pump at the discharge of one intermediate runner and returning it again to the suction of the next runner. Each main unit is supplied with one of these combination pumps driven by a variable speed, direct-current motor. The motor speeds are controlled by hand to regulate feed water pressure and distribution of condensate flow between main units.

It is quite obvious that the speeds at which these pumps are operated depend upon the demands of the boilers and that some other provision must therefore be made to maintain a proper rate of condensate removal from the condenser. Also, the total quantity of water held by the boilers varies greatly with load so that a certain amount of flexibility is required with respect to the water content of the system. This is provided in two ways. First, the lower part of the condenser shell is built in the form of a large, deep box or "bath tub" giving a hot well of large storage capacity and capable of permitting a relatively great variation of condensate level. Second, further flexibility is secured by introducing large storage tanks.

Floats operated by high and by low water in the condenser hot well put these storage tanks into and out of use in the following way. If the water level rises too far it indicates that the condensate pump is not removing water fast enough, that is, that under existing conditions, the boiler feed pump is not taking water as fast as the condenser is making it. If the water level rises far enough, the high level float opens the right hand valve of the two marked "Float Controlled Storage Valves" in Fig. 10, thus permitting the condensate pump to discharge into the storage tank in addition to discharging into the suction of the boiler feed pump. On the other hand, if the water in the hot well drops to the limiting lower level the low level float opens the left hand valve of the two indicated and permits water to flow from storage to the condenser, thus giving the condensate pump a supply commensurate with the demands of the boiler feed pump. To prevent excessive oxygen content and resultant rapid corrosion of the steel tube economizers, provision is made for steam sealing of the storage tanks and, in addition, the water discharged from them into the condenser is admitted in such a way and place as to ensure maximum deaeration.

The condensate discharged by the hot well pumps of the condensers on the auxiliary turbines already described is discharged into the lines connecting with the storage tanks as shown in Fig. 10. This arrangement results in the deaeration, in the main condenser, of all water coming from the small units which are more apt to develop air leaks at low pressure turbine shaft seals and at hot well pump shaft seals.

Each main unit is provided with a duplicate steam driven combination pump. This is exactly like the motor-driven outfit just described, except that it is driven by a single-stage steam turbine instead of by a motor. This steam driven unit will be used only in emergency and then it will be started without prelimin-

ary warming up, if necessary, and will exhaust to the atmosphere as shown in Fig. 10. If the conditions require this pump to operate for any length of time the valve shown to the left of its exhaust line will be opened so that the turbine driving it will discharge into the main condenser. Such operation will be resorted to merely for the purpose of saving the steam which is all made from distilled water.

It will be noted from the diagram in Fig. 10 that the make-up for the station is supplied by a single effect evaporator taking its steam from the 14th stage bleeder connection and normally discharging its vapor to a condenser located on the high side of the 17th stage bleeder heater. When operating in this way the evaporator is capable of producing about 1¼ per cent make-up. A greater production can be obtained by increasing the temperature head and provision is therefore made for discharge of evaporator vapor to the 19th stage bleeder heater connection as shown.

Under normal operating conditions the temperature of feed water entering economizers will vary between about 200 and 250 deg. fahr., depending upon the vacuum carried in the main condensers and the loads on the main turbines. Higher values could have been obtained easily but the values chosen seemed to give the best commercial solution when cost and performance of economizers were taken into consideration. Higher values could have been used if air heaters had been installed instead of, or even possibly in addition to, economizers. However, at the time this plant was designed the air heater was considered to be very decidedly experimental. In addition, the furnace walls were to be air cooled and nothing was known about maximum permissible temperatures for air used for this purpose nor maximum permissible temperature for air entering the furnace interior.

The summary at the end of this paper gives essential data with respect to all major equipment and the more important minor equipment. Taken in combination with the motor data given in Table I it gives in convenient form most of the important information in connection with the apparatus installed. Further details of the ideas and theory underlying the design of the plant and of the equipment can be obtained by referring to the following three articles which have been published in the technical press:

1. The Trenton Channel Plant of the Detroit Edison Company; C. H. Berry; *Power*, May 27, 1924; Page 848.
2. Design Features of Trenton Channel, P. W. Thompson; *Electrical World*; May 31, 1924; Page 1115.
3. Unusual Electrical Features Found in Trenton Channel Station; *Electrical World*; January 31, 1925; Page 247.

SUMMARIZED STATEMENT OF MAJOR EQUIPMENT

Main Generating Units. Three 50,000-kw. single-barrel horizontal turbines driving three 62,500-kv-a., three-phase, 60-cycle generators with direct-connected exciters. Turbines operate at 1200 rev. per min., have 21 stages, a water rate (at 42,500 kw. without bleeding) of 9.4 lb. per kw-hr. when supplied with steam at 375 lb. gage and 700 deg. fahr. Turbines are bled at 19th, 17th and 14th stages. The nominal generator voltage is 12,200.

Generator Air Coolers. Horizontal, finned-tube cooler contained in housings within generator foundations. Coolers arranged for circulation of condensate or water from intake tunnel of plant.

Main Condensers. Three 47,300-sq. ft., single-pass condensers arranged with steam belt. Tubes are made of 70 per cent Cu, 28 per cent Zn and 1 per cent Sn alloy, 1 in., No. 18 Stubbs gage and are arranged in single lines converging from a maximum spacing at top of condenser of 4 in. to the minimum possible with 1 in. tubes at entrance to air cooler. Each condenser is equipped with two 60,000-gal. per min. circulating pumps driven by direct-connected variable speed d-c. motors; two condensate pumps one of which is mounted on shaft of motor-driven boiler feed pump and one on shaft of steam-driven boiler feed pump; one vertical reciprocating dry vacuum pump.

Main Hotwell and Boiler Feed Pumps. Hot well and boiler feed pumps are mounted on same shaft. There are two for each main unit, one driven by 700-h. p. adjustable-speed d-c. motor and the other by a 750-h. p. steam turbine. The steam-driven pump has a capacity of 1300 gal. per min. at 1700 rev. per min. and the motor-driven pump has a capacity of 1300 gal. per min. at 1200 rev. per min.

Main Generator Switches (12,200-volt). Three switches one for each main unit. Each switch is a 4000-ampere, 25,000-volt oil switch with motor-operated mechanism.

Main Step-Up Transformers. Each main unit has three, single-phase, 21,000-kv-a., 12,000, 120,000-volt, oil-insulated, water-cooled, outdoor-type transformers.

Main Generator Outdoor Switch (132,000-volt). Each main generator has two three-phase, 400-ampere, 132,000-volt outdoor-type oil switches, each phase in separate oil tank. Each switch is motor operated by centrifugal operating mechanism.

Direct-Current House Service Machines. Three 4000-kw. units, each unit consisting of cross-compound steam turbines driving through a reduction gear, two shunt-wound, interpole, 2000-kw., d-c. generators mounted on a single shaft. High-pressure element operates at 4000 rev. per min., low pressure at 3000 rev. per min. and generators at 360 rev. per min.

Condensers for Direct-Current House Service Machines. Three 7500-sq. ft., two-pass condensers completely equipped with circulating pumps, hotwell pumps and air pumps.

Alternating-Current House Service Machines. Two single-barrel turbines each driving one 2000-kw. three-phase, 60-cycle, 2300-volt generator with direct-connected exciter, at 3600 rev. per min.

Condensers for Alternating Current House Service Machines. Two 4100-sq. ft. two-pass condensers equipped with circulating pumps, hotwell pumps and air pumps. These auxiliaries are driven by a-c. motors and can be brought up with machine if desired, priming being taken care of by priming header running the length of the plant.

Main Steam Piping. VanStone joints with gaskets.

Main Turbine Room Crane. One 125-ton crane with span of 97 ft. 6 in. Can handle circulating pumps and other auxiliaries on condenser room floor as well as main unit parts.

Boilers. Eight 29,085-sq. ft., five-drum, curved-tube boilers built for operating pressure of 416 lb. on drums and equipped with two superheaters per boiler which give total steam temperature of 700 to 725 deg. fahr.. A hearth screen is used at the bottom of furnace under each boiler but is entirely separate from the boiler in so far as circulation is concerned. Each hearth screen consists of two separate boilers with independent feed. Steam made in these boilers joins steam made in main boiler and the combination passes through superheater of main boiler. Boilers are arranged in groups of three across main axis of boiler house and are fired from both ends thus giving four firing aisles srunning lengthwise.

Pulverized Fuel Preparation and Handling Equipment. Fourteen steam-heated air-circulating driers feeding coal to 14 pulverizing mills. Pulverized coal raised from mill to cyclone separator by No. 12 mill exhauster, one exhauster per mill. Exhausters driven by 60-h. p. a-c. motors. Mills driven by 100-h. p. a-c. motors. Coal from cyclone separators forwarded by four screw-conveyors running lengthwise of house to hopper over three 10 in. pulverized coal pumps. These pumps driven by 60-h. p. a-c. motors.

Pulverized Fuel Burning Equipment. Sixteen burners per boiler, eight on each end, fed by duplex feeders driven by two-h. p. adjustable-speed d-c. motors. Primary air for each boiler supplied by two 55-in. blowers driven by 30-h. p. variable speed d-c. motors.

Boiler Furnaces. Air-cooled, refractory-wall type with eight burners at opposite ends. Distance, arch to hearth screen, 20 ft; distance between opposing rows of burners 29 ft; distance center line of burners to adjacent wall 2½ ft.; distance between burners 2 ft. 4 in.; distance end burner to side wall 3 ft. 4 in.; inside width furnace 23 ft.; total volume from hearth screen to peak of furnace 25,140 cu. ft.

Ash Handling. All ash collecting in furnace and in boiler passes, flues and economizer hoppers, is discharged to hydraulic sluice way running longitudinally in boiler house basement and is sluiced to settling basin. Material removed from settling basin by centrifugal dredge type pump and used for filling on property.

Economizers. Two, steel-tube economizers per boiler with 9492 sq. ft. of surface per economizer. Tubes are plain, 2-in. tubes rolled into rectangular forged headers.

Induced Draft Fans. One double-inlet, 193,000-cu. ft. per min., at 375 deg. fahr., induced draft fan per boiler, capable of producing maximum draft of 7.15 in. water at fan. Each fan driven by 350-h. p. adjustable-speed d-c. motor. Three fans serving one row of three boilers discharge through curved flues into single stack.

Stacks. One stack for every three boilers. Stacks have Venturi shape with inside diameter of 15 ft. ½ in. at throat and 21 ft. at top. Top of stack is 192 ft. above burners. Stack is self-supporting steel, carried on building steel and is brick lined.

A New Method and Means for Measuring Dielectric Absorption

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Associate, A. I. E. E.

Synopsis.—*The progress of practically all electrical apparatus is, to a large degree dependent on progress in insulation. The successful selection and use of insulation, particularly insulation operated with maximum economy as in the case of static condensers, depends on our progress in the understanding of the factors on which insulation quality depends.*

It has long been known that for a given working condition, reliability depends on dielectric losses, particularly the losses commonly referred to as hysteresis losses.

The hysteresis loss is definitely related to the phenomenon of absorption or residual charge, especially when the residual voltage quickly builds up.

In order to further analyze dielectric losses, and study the progress of treatment of insulation, a device has been developed for measuring dielectric absorption.

This article describes the "Dielectric Lag Meter" and gives some test data secured by it.

* * * * *

I. Introduction

The importance of insulation to the progress of the electrical art is well recognized. This is especially so in apparatus where insulation is operated with maximum economy, as in the case of condensers and cables. Possibly the most important of all insulation from the standpoint of relation to the cost and reliability of the apparatus is that used in condensers, since in condensers the insulation is the vital element, the active part, and fundamental to the device itself. More than that, the quantity of insulation varies inversely as the square of the stress at which the material is worked. The working stress must at all times be well within limits which have been established as reliable, nevertheless as we acquire knowledge of the fundamentals of insulation, we shall be able to fabricate it more economically and operate with less, but more definite factors of safety.

Insulation may be divided into two general classes: viz., (1) That occurring in a natural state, (2) That which is created by combination of other materials. Under the first class we have mica, and similar substances, while under the second class we have fibrous spacer materials impregnated with oils, waxes or similar substances. The practical disadvantage of the first class is that the quality is not under our control. We can only make suitable tests to select the material of satisfactory quality. Insulation of the second class, while of a complicated nature, is subject to closer control since practically all the materials making up the structure may be controlled to a greater or lesser degree. It is only necessary to exercise the proper control when a means is available by which the quality of the various materials can be studied separately, combined and during the process of combination.

The advantages of oil-impregnated paper insulation are now fully recognized and this type of insulation has been used with success for many years. This form of insulation can be used in large quantities due to its

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inherent uniformity. A closer control, however, during impregnation, will result in still greater gain, since a large mass of insulation may be treated until every unit of its volume is of satisfactory quality. The principle advantages of oil-treated paper insulation are the high quality of oil as an impregnating medium, the circulating or heat distribution qualities and the thoroughness with which it impregnates the material.

It is extremely important that practically all the moisture be removed from the paper before the introduction of oil, and, in fact, the characteristics of the dielectric consisting of high grade paper and oil depend almost entirely on the completeness of moisture removal before impregnation.

Many methods have been developed, whereby the finished condenser, or cable, may be tested for dielectric losses. Such tests are extremely important, especially when one is concerned with the efficiency or temperature rise. On the other hand, these tests give only the result of imperfections and not the nature of the losses. In other words, the losses in the condenser may be caused by losses in the metal plates, conduction losses, or the so-called hysteresis losses in the dielectric itself.

It is desirable not only to analyze these losses, but to make the tests on the condenser during treatment.

In the case of 60 cycles, practically all of the loss is in the insulation itself, rather than in the metal plates or due to conduction through the dielectric. It is generally agreed that the losses in the insulation are directly related to the phenomenon of absorption. A measure of absorption during treatment should serve as a very effective quality control.

A device for conveniently measuring absorption has been worked out and it is the purpose of this paper to describe this device in detail.

II. Dielectric Absorption

When a condenser having a perfect dielectric is connected to a source of electromotive force, it immediately takes up a quantity of electricity, Q_0, which is proportional to the voltage:

$$Q_0 = C_0 E$$

Where C_0 is the geometrical capacity, or the capacity based on the physical dimensions of the insulation and specific inductive capacity.

However, in the case of an imperfect dielectric, the above does not complete the process. The quantity Q_0, increases with time until a final value, Q_∞, which exceeds the value Q_0 by a certain fraction K, is reached.

$$Q_\infty = (1 + K)\, Q_0 E$$

This characteristic of insulation has been given the name of dielectric absorption and the key to an understanding of insulation losses lies in the thorough understanding of this phenomenon.

As stated above, the initial quantity of electricity may be represented by Q_0. This is also the quantity that will be dissipated on a quick short circuit or discharge through a low resistance. Thus, when a condenser is charged, discharged and then left open-circuited, a voltage will build up with time across its terminals. The rate at which this voltage builds up, and the magnitude of the voltage for a given condenser, depends on the time of charging and applied voltage. With different condensers, the shape of this residual curve, especially when different applied voltages are considered, depends on the quality of the insulation.

Our work has indicated that these curves, if fully understood and analyzed, will provide a measure of at least the major factors on which dielectric quality depends.

The most desirable method for measuring absorption direct, is to charge the condenser for an arbitrary, but short length of time, then discharge it through a very low resistance to eliminate the quantity Q_0 and measure the residual voltage as it builds up after discharge.

The subject of dielectric absorption has occupied the minds of many investigators over a long period. There are some who account for it entirely on the basis of heterogeneity, while others consider it of a more complicated nature.

F. W. Grover* has reviewed a number of these theories and analyzed them quantitatively.

K. W. Wagner† has made a careful study of the Maxwell‡ theory of absorption and has applied it to a more complicated dielectric structure.

Difficulty of Measuring Absorption

Many investigators have measured absorption by charging the condenser, discharging it, and immediately connecting across its terminals, an electrostatic voltmeter. This is not wholly satisfactory, since the static voltmeter has a large time lag and fails to indicate the values of voltage during the most important part of the residual-voltage curve. Our tests of this kind showed that the part of the residual curve, occurring during the first ten seconds, is not secured. Further investigations showed first, that the most important part of the residual voltage curve occurs within the first second, and secondly, that, after a few seconds, the true shape of the residual curve is distorted by leakage current due to the over-all insulation conductivity.

It is desirable, therefore, to make the absorption measurements within one second after discharge and a sufficient number of measurements should be taken during this period of time to establish with reasonable accuracy the shape of the curves.

The Dielectric Lag or Absorption Meter

The dielectric lag meter measures the instantaneous values of voltage across the condenser by direct comparison with known voltages.

*F. W. Grover, Bulletin of the Bureau of Standards No. 4, December 15, 1911.

†K. W. Wagner, Theory of Dielectric after Effect in the light of Maxwell's notions.

Archiv fur Elektrotechnik, Vol. 2, No. 9, 1914.

‡Clerk Maxwell, *Electricity and Magnetism*, Vol. 1, page 452.

The apparatus consists of an arm switch rotating at a constant and known speed, a potentiometer for varying the value of the known voltage, a galvanometer circuit and a means for selecting the instant of time at which the measurement is to be made.

The diagram in Fig. 1 shows the rotating arm switch with twelve stationary contacts, the galvanometer and potentiometer circuits, and, in addition, a variable resistance in parallel to the condensers. The variable resistance is not used in making residual voltage curves, but is provided for making discharge curves which are described later.

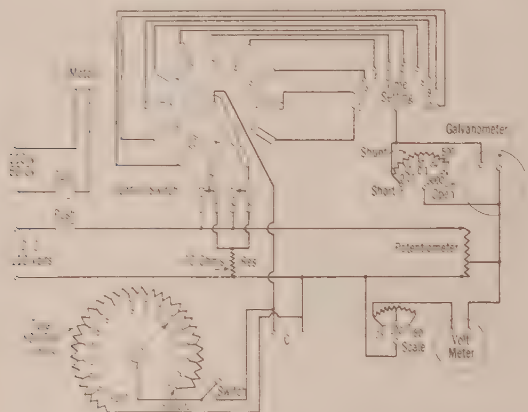

Fig. 1—Diagram of Connections of Dielectric Lag Meter

Three different types of test which may be made by means of this instrument have been found to be of particular value:

A. *Residual voltage against time*

B. *Residual voltage against applied voltage*

C. *Discharge curves with condenser and resistance.*

The methods of making these tests are discussed separately and in detail to illustrate the operation of the instrument.

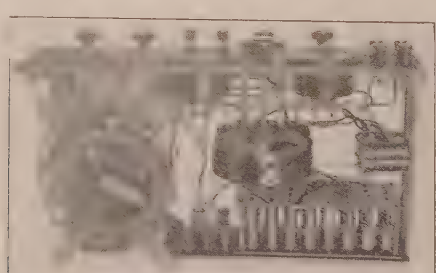

Fig. 2—Internal View of Dielectric Lag Meter

A. Residual Voltage Against Time. The condenser to be tested is connected at terminals marked C in Fig. 1. The shunt resistance is disconnected for this test. The two terminals marked D. C. are connected to a source of direct current. The other two terminals are connected to the 110 volts, 60 cycles, for operating the synchronous motor driving the arm switch.

Two segments are used for charging and discharging the condenser while the other ten segments are used for measuring the residual voltage at various values of time after discharge.

The charge and discharge segments are connected to the line and discharge resistance, marked 60 ohms on Fig. 1, by means of the switches C, D, C, D, so that when the arm is rotating counter-clockwise the first segment will charge the condenser to the applied voltage and the second, will discharge it. The width of the charging segments and the space between it and the discharge segment are such as to fix the charging time at 0.111 seconds. The discharge resistance is made just high enough to prevent damage to the segments on the discharge and not high enough to fail to discharge the initial quantity Q_0.

In making the tests the arm makes contact first with the charging segment, then with the discharge segment, and then makes a complete revolution and charges again and so on at a constant rate. Each time the arm leaves the discharge segment and as it makes its revolution a residual voltage develops each time taking on the same values for the periods of time corresponding to the segments 1, 2, 3 to 10, consecutively.

While this is going on, the time-setting switch, shown

Fig. 3—Front View of Dielectric Lag Meter

on diagram Fig. 1, is set on contact one and the potentiometer voltage adjusted until the potential of segment No. 1 is the same as that of the rotating brush at the particular instant of time that it comes in contact with segment No. 1. This condition is obtained by adjusting the potentiometer until the galvanometer fails to reflect in either direction, when the arm makes contact with this segment. When the balance is obtained, the voltage setting of the potentiometer is equal to the condenser voltage at the instant of time corresponding to the position of segment No. 1, which is located 0.111 seconds after discharge. This is repeated for segments 2, 3, 4, etc., thus giving 10 points on the residual curve, 0.111 seconds apart.

B. Residual Voltage Against Applied Voltage. In this case the time-setting switch is left in some one position and the residual voltage measured for different applied voltages by balancing with the potentiometer as in *a*.

C. Discharge Curves with Condenser and Resistance.

Discharge curves are less important than the residual voltage curves, since more factors are involved. The departure of the curve on a condenser from the theoretical equations

$$E = E_0 \times e^{-\frac{T}{rc}}$$

is quite noticeable with the slightest amount of absorption. This is especially true with discharge curves of very short duration and the lag meter is especially suited for making these discharge curves.

In making discharge curves, the charge and discharge segments are changed so that the condenser is first discharged and then charged to line voltage. This is accomplished by means of switches C, D, as will be seen by referring to Fig. 1. In this case the condenser voltage is that of the line voltage when the arm starts its revolution and drops during the course of the revolution, due to the discharge resistance which is shunted across it. The variable discharge resistance should be set at a value, depending upon the capacity of the condenser, so that the voltage at segment 10 will be of the order of one volt, thus giving 10 points on the discharge curve. Steeper discharge curves may be made, if desired, where the voltage has already reached practically zero value at segment two or four or even one. The values of voltage for segments, consecutively from one to ten are determined as before.

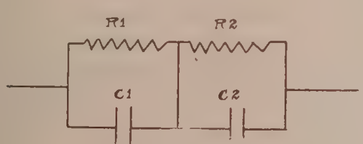

Fig. 4—Model Condenser to Illustrate Maxwell's Theory of Absorption

The details of the device, especially the arm switch, are shown in Fig. 2. The front with all control knobs is shown in Fig. 3.

Dielectric Absorption Measurements with "Lag Meter"

Three types of test are described below to illustrate the performance of the device:

1. Dielectric absorption tests on a model condenser made to illustrate Maxwell's theory of absorption.
2. Dielectric absorption tests on a paper condenser during removal of moisture to show effect of moisture removal on absorption.
3. Tests on miscellaneous power condensers.

1. Model Condenser

Clerk Maxwell showed in his famous Treatise on Electricity and Magnetism that a dielectric, having a variation in the product of R and C, at varous points would exhibit the phenomenon of absorption. That is, the initial voltage distribution would follow the values of C and a later or final distribution would follow the values of R. If the distribution according to values of R, does not agree with the distribution for the values of C correspondingly, a shift will take place in the stored charges. This charge represented by the shift from the normal condition will not come out instantaneously when the condenser is discharged, but will come out with time after discharge, resulting in a residual voltage.

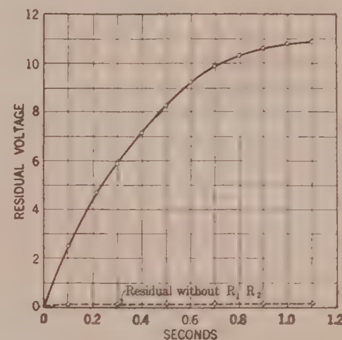

Fig. 5—Residual Voltage Against Time for Model Condenser Shown in Fig. 4

A model condenser was constructed to illustrate this and measurements of the residual voltage were made with the lag meter. This model consisted of two condensers C_1 and C_2 shunted by a resistance R_1 and R_2 as shown in Fig. 4. No attempt was made to make the values representative of an actual condenser. The two condensers used to make this test had extremely low residual voltages, so that for all practical purposes the residual values obtained were due only to the fact that $R_1 C_1$ was not equal to $R_2 C_2$. Tests were also made with values of R_1 and R_2, so that the two products $R C$ were equal and no residual voltage was obtained in excess of that which would exist without the resistances.

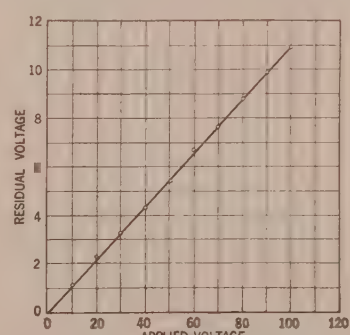

Fig. 6—Residual Voltage Against Applied Voltage for Model Condenser Shown in Fig. 4. Time After Discharge Equals 1.11 Seconds

The residual voltage against time for the model as shown in Fig. 4 is given in Fig. 5.

The residual voltage against applied voltage for T after discharge = 1.11 seconds, is given in Fig. 6.

This shows that the residual voltage is proportional to the applied voltage for such a model as would be expected from Maxwell's equations.

Fig. 7 shows discharge curves made, using the above model and with resistances of 31,000; 50,000; 135,000

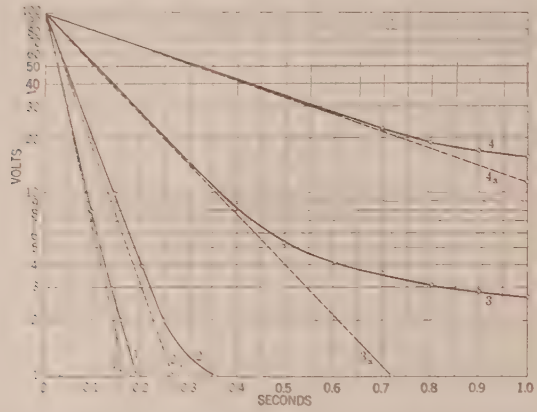

FIG. 7—SHOWS DISCHARGE CURVES MADE USING MODEL FIG. 4

and 400,000 ohms. The model follows qualitatively Maxwell's theory of absorption.

2. DIELECTRIC ABSORPTION TESTS ON CONDENSERS DURING TREATMENT TO REMOVE MOISTURE

A stacked paper condenser having a capacity of approximately 3 microfarads was dried in an oven with vacuum in order to remove moisture, in accordance with

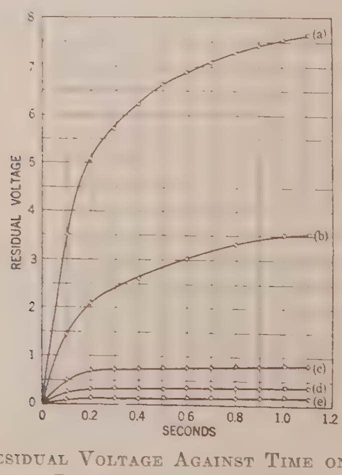

FIG. 8—RESIDUAL VOLTAGE AGAINST TIME ON A CONDENSER DURING MOISTURE REMOVAL

the usual process. Five residual voltage curves were taken, one just after heat treatment before vacuum was applied and the other four during heat treatment with vacuum. In each case the condenser was allowed to cool to 22 deg. cent. before making the test. The five curves Fig. 8, are identified as follows:

a. Heated the day before 6 hours at 60 deg. cent.

b. Heated the day before 6 hours at 100 deg. cent. and 27 in. vacuum.

c. Heated the day before 6 hours at 100 deg. cent. and 28 in. vacuum.

d. Heated the day before 6 hours at 100 deg. cent. and 28 in. vacuum.

e. Heated 16 additional hours at 100 deg. cent. and 28 in. vacuum.

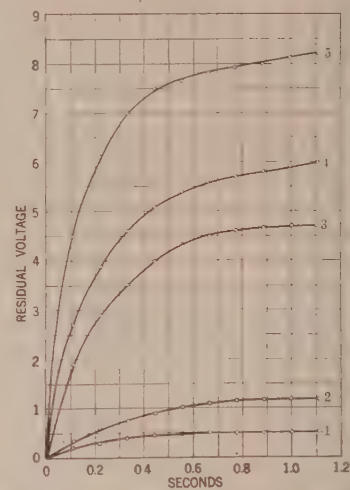

FIG. 9—RESIDUAL VOLTAGE CURVES ON TYPICAL POWER CONDENSERS

As the moisture is removed from the dry paper condenser the residual voltage decreases to a value which is practically immeasurable, as shown by the above curves. This is due to the fact that the dry paper has very little absorption in itself.

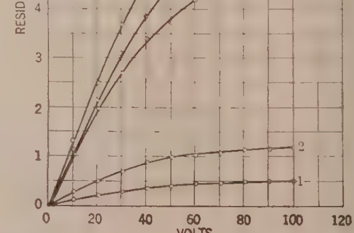

FIG. 10—RESIDUAL VOLTAGE CURVES AGAINST APPLIED VOLTAGE FOR TYPICAL POWER CONDENSERS

3. TESTS ON MISCELLÁNEOUS POWER CONDENSERS

In order to illustrate the values of residual voltage obtained with average commercial power condensers curves are given in Fig. 9 for five different condensers each of the same style but varying somewhat in quality. These curves show that for a very high

quality condenser, having losses of about 0.2 per cent as designated by Curve No. 2, the residual voltage is very low, while for a condenser having power losses such as 0.5 per cent the residual voltage is very much higher, as shown in Fig. 8, Curve No. 5. It must be borne in mind, however, that a direct comparison cannot be made between losses and residual voltage unless all factors are taken into consideration, and in fact, the exact relation existing has not been definitely established. These tests are made on 5-kv-a. 2300-volt condenser units.

Fig. 10 gives the five residual voltage curves against the applied voltage for the same condensers as covered by Fig. 9. Corresponding numbers are given to the two sets of curves for comparison.

It is of greatest importance to note that in Fig. 10 the residual voltage curves against applied voltage have a saturating characteristic, that is, at some voltage for each condenser the residual voltage reaches a maximum value or approaches a maximum value as a limit, instead of being at all times proportional. It is of even more interest to note that the higher the quality of the condenser, the smaller the angle of rise becomes.

Conclusions

All tests to date indicate that the residual voltage against applied voltage and residual voltage against time are of greatest value.

The saturating characteristics of residual voltage against applied voltage appears to be the most important of all, in that it follows so closely the over-all quality of the condenser and it is our opinion that a thorough understanding of this curve will result in a better understanding of the factors on which insulation quality depends. This saturating characteristic is not accounted for by previous work or theories, so far as we have been able to learn.

The immediate value of the absorption test is in determining when the moisture has been removed from the paper during treatment, so that in no case will the oil be applied until the moisture has been removed.

A measure of absorption may show the progress of the oil in reaching the microscopic crevices of the fiber.

After the factors affecting the absorption are understood, absorption tests may be of value in periodically testing cables in service, to show stratified deterioration and serve as a means of anticipating cable failures.

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MORE PERMALLOY CABLES TO BE LAID

The Pacific Coast Board has placed an order for a new submarine cable to be laid in the Pacific Ocean from Victoria, Canada, to Suva, capital of the Fiji Islands. The southern section of this cable, running from Fanning Island to Suva, will be inductively loaded with permalloy, the newly discovered magnetic alloy.

Permalloy, the most highly magnetic substance known, is an alloy of nickel and iron and was first employed in the New York-Azores cable laid last year. Through its use the speed of sending is increased five times over the highest speed previously attained in the use of submarine cables. Existing apparatus was altogether inadequate for receiving messages at such speed, and an entirely new type of terminal equipment was designed. With this, six automatic printing machines are simultaneously used at each end of the line to record the messages as they come over the cable. The new permalloy cable is transmitting 1600 words a minute as against 200 words possible in old-style cables.

Permalloy is applied to the copper conductor of the cable in the form of a slender ribbon which surrounds the conductor with a magnetic field. The effect of this is to prevent distortion and attenuation of the signals.

Two other important cable projects will make use of permalloy, one of which will be a cable laid from Penzance, England, to Bay Roberts, Newfoundland, where it will connect with the second cable, to be laid from that point to New York. It is estimated by cable experts that this cable will have a traffic carrying capacity of 100,000,000 words a year.

German engineers are now in the United States making investigations which are expected to lead to the laying of a permalloy cable from the Azores to Emden, Germany. This will link with the cable laid last year from New York to the Azores, and furnish the first direct route to Germany since the war. The loading with permalloy throughout both sections of the new route will greatly add to the importance of this cable.

Radio

Government control of all broadcasting activities in Denmark for the period of one year, namely, from April 1, 1925, to March 31, 1926, was recently put into effect. A special board of some 27 members, including, among others, Government officials, representatives of the various radio organizations, the press, and prominent professional singers has been appointed to take charge of the preparation of all radio programs.

Hydrogen as a Cooling Medium for Electrical Machinery

BY EDGAR KNOWLTON[1] CHESTER W. RICE[1] E. H. FREIBURGHOUSE[1]

Members, A. I. E. E.

Synopsis.—*This paper presents the results of a large amount of theoretical study and a large number of tests to determine the advantages of hydrogen as a cooling medium in electrical machiney.*

The conclusions fall into two classes, some definite and some specutative. In the former class are:

1. For the same operating temperature a steam turbine-driven generator of a given size will have a capacity at least 30 per cent greater when operated in hydrogen than when operated in air.

2. The efficiency will be 1 per cent or more higher.

3. There will be no danger of fire destroying the insulation.

4. The detrimental effects of corona if present will be greatly reduced.

5. The machine may be protected by suitable devices from the formation of an explosive mixture of hydrogen and air.

6. The frame can be made sufficiently strong to resist an explosion. This is additional security in case of failure of the protective devices or negligence in operation.

7. The cooler for removing the heat from the hydrogen may be considerably smaller than a cooler for removing heat from air.

In the speculative class are:

1. A hydrogen pressure of several atmospheres will result in still greater possibilities provided a sufficiently gas tight enclosure can be developed.

2. The insulation may be made thinner and still have as long a life as the present insulations operated in air.

I. Introduction

SEVERAL years ago, Dr. W. R. Whitney suggested in a note to one of the writers the desirability of studying the problem of using hydrogen as a cooling medium for large electrical machinery. He pointed out that it is purely an accident that our machines are operated in air and that an atmosphere of hydrogen was much more favorable for the following reasons:

1. Less windage loss, because of the low density of hydrogen.
2. Cooler, because of high heat conductivity of hydrogen.
3. Less damage due to electrical failure, because the insulation cannot burn.

This suggestion of Dr. Whitney led to an extensive study of the characteristics of hydrogen and other gases as cooling media.[2,3,4] An investigation of the windage losses has also been reported.[5] A subsequent investigation showed that the idea of using hydrogen as a cooling medium in electrical machinery was proposed some years earlier by Max Schuler.[6]

The most desirable application of hydrogen as a cooling medium is to machines having both a relatively large windage loss and adverse cooling factors. These occur in all steam turbine-driven alternators, especially those which at present seem to be approaching the maximum desirable capacity for a given speed. The use of hydrogen as a cooling medium will in such cases allow a greater capacity for a given speed and obviate the necessity, for certain capacities, of reducing the speed or changing to methods of ventilating that are less favorably considered. For example, for an air-cooled machine of a given capacity and speed, it may be necessary to use external blowers for circulating the air whereas if the same capacity of machine was cooled by hydrogen the fans could be placed on the rotor.

In certain cases of air-cooled machines, with fans mounted on the rotor, the power to drive the fans becomes excessive if the fans are designed to circulate the maximum quantity of air which can be obtained with the diameter and speeds chosen. It is customary in such cases to be content with a lesser quantity of air than is otherwise desirable. With a hydrogen-cooled machine a 25 or even a 50 per cent increase in power to drive the fans is of no relative importance.

II. Characteristics of Hydrogen

The important characteristics of hydrogen when compared with air as a cooling medium for large high speed electrical machines are:

A. Lower density.
B. Higher thermal conductivity.
C. Higher forced heat convection.
D. Practically no damage to insulation by corona.
E. Prevention of fire.

A. Lower Density. Tests in hydrogen showed a windage loss of 10 per cent of that in air, which agrees with the chemical analysis of commercial hydrogen. The total losses of large capacity alternators of 1800 or 3600 rev. per min. amount to approximately 2½ per cent and the windage loss is one or more per cent of the rated capacity. By operating such a machine in hydrogen the windage loss is practically eliminated and results in about 1 per cent increase in efficiency.

B. High Thermal Conductivity of Hydrogen. Hydrogen has approximately seven times the heat conductivity of air or as high a thermal conductivity as the

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1. All of General Electric Co., Schenectady, New York.
2. Chester W. Rice: "Free and Forced Convection of Heat in Gases and Liquids," Trans. A. I. E. E., Vol. XLII, p. 653, 1923.
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5. Chester W. Rice: "Windage Losses in Air, Hydrogen and Carbon Dioxide," *G. E. Review*, May, 1925.
6. Max Schuler, American Patent No. 1,453,083. Filed Oct. 25, 1916. Issued April 24, 1923.

ordinary insulating materials. When a machine is operated in air any spaces in the insulation, or between the insulation and slot sides, appreciably increases the thermal drop from the copper to the surface from which the heat is to be removed by the air. With hydrogen in the machine the gas spaces are no longer harmful in this respect, because of the greater heat conductivity of the hydrogen. To illustrate the effect, consider an extreme case in which the armature insulation is 7/32 in. thick and the spaces aggregate 1/64 in. additional. The following table gives the thermal drops in both cases with an energy flow of 0.32 watts per square inch through the insulation, assuming a thermal resistance of 270 deg. cent. which is closely true for the type of insulation considered.

	Air	H_2
Drop through insulation	17.5 deg. cent.	17.5 deg. cent.
Drop through gas spaces	9.	1.25
Drop, total	26.5 deg. cent.	18.75 deg. cent.

An additional gain will be made in the thermal drop in those heat paths in the armature core and teeth which are parallel to the axis of the armature, since the spaces between the laminations will be filled with hydrogen. The ratio of the temperature drop in a hydrogen atmosphere to that in air would be about 65 per cent in this case.

C. Forced Heat Convection. The efficiency of heat removal by high velocity gas blowing over the surfaces is approximately 1.3 times as great in commercial hydrogen as in air. In other words, the surface film temperature drop required in the hydrogen machine to transfer one watt per sq. in. is 77 per cent of that required for the same machine in air.

The machine under consideration is totally enclosed, and the heat is removed from the circulating air, or hydrogen, by tube and fin surface coolers, provided with water circulation. The rate of heat transfer from hydrogen to a single tube in commercial hydrogen at the usual velocities is approximately three times as great as for the same tube in air at the same velocity. Somewhat the same ratio is expected in the case of built-up coolers, since the spacing between the tubes will be large compared with the film thickness, and the mutual influence of the tubes should be small. Accurate tests, are, of course, needed to determine the exact ratio.

Effects of Lower Density and Greater Conduction and Convection. We may summarize the temperature conditions for the machine in hydrogen and air as follows:

1. The practicable absence of windage loss when hydrogen is used results in less heat to be removed from the machine.

2. The temperature drop required to transmit a given amount of heat from the copper to the iron, through the insulation, will be materially lower in hydrogen. The temperature drop required to transmit heat across the laminations will also be lower in hydrogen than in air.

3. The temperature drop required to transmit the heat from the surface to the high velocity ventilating gas will be less in hydrogen than in air.

4. When the gas reaches the cooler, less temperature difference will be required to remove the heat from hydrogen than from air, and, therefore, the hydrogen will be cooler when it returns to the machine.

The accumulative effect of all these factors is considerably lower copper and insulation temperatures, and the advantage may be used either to increase the life or the capacity of the machine as seems most desirable.

D. Corona in Air and Hydrogen. The potential gradient at which corona starts in hydrogen is approximately 60 per cent of that at which it starts in air.[7] Thus a machine designed to operate in air without corona might produce severe corona when operated in hydrogen at atmospheric pressure. The destructive nature of corona in air on insulation is well known and it was, therefore, feared that insulation troubles would soon develop, if a standard machine without corona shields were operated in hydrogen. To test this point some preliminary comparative endurance tests were made in hydrogen and air on two similar samples of yellow varnished cloth. These samples were made by winding the cloth around glass tubes, approximately ¾ in. in diameter by 7 in. long, until thirteen layers were obtained. The inner electrode consisted of a ½ in. diameter copper tube, which was slipped inside of the glass tube, and the outer electrode consisted of several widely spaced turns of 0.01 in. diameter cotton covered wire extending over approximately 1 in. of the central portion of the cloth. One sample was contained in a glass bell jar through which hydrogen at atmospheric pressure was slowly circulated, and the other was placed in the open air. The samples were connected in parallel across the terminals of a small testing transformer, and the voltage gradually raised. The tests were made in a moderately darkened room, and it was expected that corona would first be distinctly visible on the hydrogen sample, but this was not the case. On the contrary, needlelike purple streamers were first seen on the air sample. The corona in hydrogen was a very faint diffused glow. Probably in a completely darkened room the corona would have been visible in hydrogen before it appeared in air. The main point of interest was the strikingly different appearance of the corona in the two gases. In air there were vicious needlelike streamers coming out from spots along the wires, while in hydrogen the appearance of corona was soft and diffuse in character, and gave the impression that hydrogen corona would be harmless compared with air corona on the same sample and at the same voltage. A potential difference of

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Hayashi, *Ann. der Phys.* 45, p. 431, 1914.
Jensen, *Phy. Rev.* Vol. 8, p. 433, 1916.

10 kv. at 60 cycles was applied for 76 hours. Fig. 1 shows the samples with the fine wire removed. In the air sample small holes may be seen along the imprint of the wire on the cloth. Photographs were taken of the samples when unrolled, but the variations in light reflections completely masked the effects of corona, therefore a contact print was made and this was photographed to obtain Fig. 2. The samples of cloth were

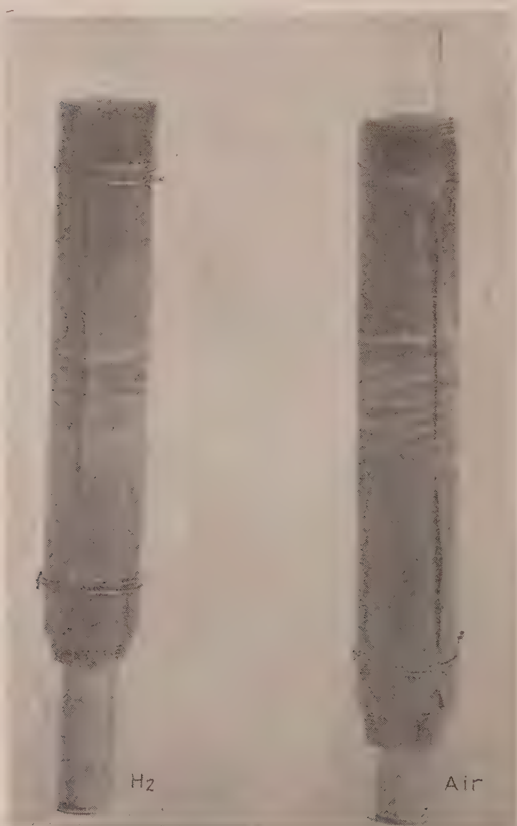

Fig. 1—Samples of Varnished Cloth Subjected to Corona in Air and Hydrogen

about three feet long, and since a reduction to the size necessary for reproduction would render the punctures invisible, only the outer and inner layers are shown in this figure. These layers are numbered 1 and 13 respectively, No. 1 being the surface on which the wire was wound, and No. 13 the layer which was against the glass tube. In both cases the intervening layers resembled to a degree those shown.

The sample in air was punctured through thirteen layers as shown in the figure. The hydrogen sample had no punctures. The only noticeable effect was the removal of the glaze on the varnished surface in the vicinity of the wire. This duller area was greatest on the outer layer, but was present on all layers. On the outer layer this removal of glaze extended over a considerably greater area in the hydrogen than in the air sample.

Different materials were tested in a similar manner for 56 hours. The damage in each case was not so great, but the same relative effects were obtained.

The appearance of corona in hydrogen resembles the appearance of corona in air at reduced pressure. It was, therefore, interesting to compare the relative destructiveness of corona in air at atmospheric pressure with that in air at reduced pressure. Some preliminary tests in air at one atmosphere and one-half atmosphere pressure indicate that the corona is not materially different in the two cases. In order to obtain more information on the question of whether corona destruction is due to mechanical or chemical effects, six layers of yellow varnished cloth were placed on a table and a drop of concentrated nitric acid placed in the center, with five drops of dilute acid surrounding it. An inverted beaker was placed over the drops to retain the acid fumes in contact with the cloth. After three days a visual inspection of the samples showed no dif-

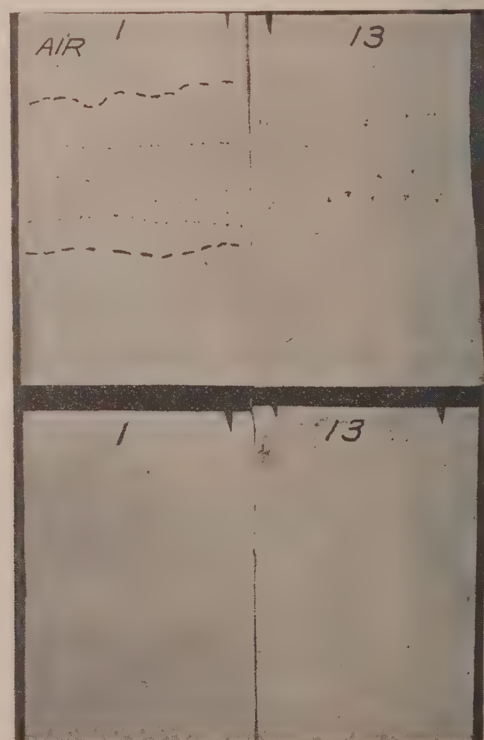

Fig. 2—Effect of Corona on Varnished Cloth in Air and Hydrogen

Two upper samples in air. Two lower samples in hydrogen. In both cases No. 1 was the surface on which wire was wound and 13 was the surface which was against the glass tube

ference between the part exposed to the acid fumes under the beaker and the portion exposed to the air. There was, however, a very marked reduction in mechanical strength in the area subjected to the acid fumes. A pencil point could be easily forced through all six layers anywhere within the beaker diameter,

whereas outside of the beaker diameter the material retained its normal strength.

It may be inferred from these tests that the destructive action of air corona on insulation is due to the mechanical weakening of the insulation by the presence of nitric acid or ozone produced by the corona, followed by erosion of the corroded material by the mechanical or blast action of the corona streamers. In hydrogen, corrosion is not produced, as no chemical action takes place, and erosion is not of itself sufficiently severe to seriously impair the life of the insulation.

Following these preliminary tests, G. B. Shanklin made corona endurance tests on eight samples of armature insulation. Four were varnished cloth and four mica tape insulation, each having a thickness of 0.23 in. Horn fibre 0.015 in. thick was moulded over the insulations and over this were wound thin copper strips ½ in. wide with a similar space between the edges. Half of the samples were placed in hydrogen at atmospheric pressure and half in air and subjected to a potential of 22,000 volts which was sufficient to produce clearly visible corona at the edges of the copper strips, in a slightly darkened room.

The two cloth samples in air failed after 2500 and 2650 hours operation. The remaining samples were tested for 8000 hours without failure.

there have been cases of fire starting on the surfaces of insulation without any electrical failure. If ventilated with air, the fire may spread with great rapidity,

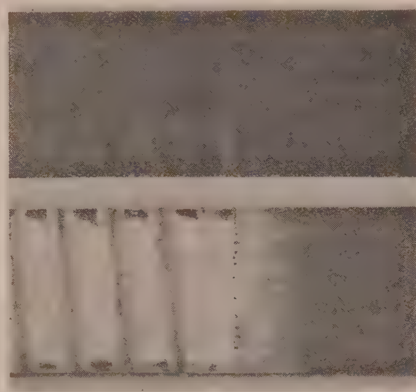

Fig. 3—Appearance of Armature Coil Insulation Subjected to Corona Endurance Tests in Air and Hydrogen

and injure the winding to the extent of requiring extensive replacement. Also a slight electrical failure, involving initially one or two coils, may start an equally serious fire. With hydrogen no fire can occur and the

TABLE 1
RESULTS OF THE OPERATION OF ARMATURE INSULATION IN AIR AND HYDROGEN

	Mica Tape in		Cloth Tape in	
	Air	H_2	Air	H_2
	No failure		Failed	No failure
Length of Test in Hours.......	8000	8000	2500 2650	8000
Appearance See Fig. 3 with copper strip removed	Fibre bleached. Pitted through fibre and next layer of cloth tape	Fibre retained original color. Fibre pitted only in a few places	Fibre partly bleached. Pitted through fibre and two layers of cloth in quite a number of places.	Fibre slightly bleached. Pitted through fibre and through two layers of cloth in a few places.
Dielectric strength test. Test started at 30.000 and increased 3000 volts each minute	60,000	63,000	31,500	48,800

Table I gives a condensed statement of the results.

None of the mica tape samples showed any pitting of the mica tape. The horn fiber covering was entirely pitted through in numerous places in the air sample but examination of the mica tape disclosed no pitting. Dissecting the insulation revealed brown powder and white powder in some places between the layers of tape of the air sample but none in the hydrogen sample. Fig. 3 shows the appearance of the mica tape samples.

A visible examination of the cloth samples would not lead one to suppose that there should be so great a difference in puncture values as shown by the tests. It seems reasonable to conclude that the cloth in air was injured considerably more than the cloth in hydrogen but not to the extent indicated by the puncture values since unknown factors may also have considerable influence on puncture values.

E. Prevention of Fire. In steam turbine generators

damage due to an electrical failure will be confined to a few coils.

Most of the large capacity air-cooled steam turbine generators are provided with pipes for the injection of steam or water in case of fire. The pipes are usually located near the ends of the windings and when the steam or water is turned on the ends of the windings are enveloped or covered by the extinguishing substance as the case may be. When there is a suspicion of a fire, the operator naturally wishes to be sure that the situation is serious before a machine is taken off the line and subjected to steam or water, and the tendency is to wait so long that damage may be done either by the fire or by the amount of steam or water that is turned into the machine. With a hydrogen filled machine no such disturbing condition can exist. The only failure to be considered is an electrical short circuit or ground, and the well known automatic devices now

available should remove the machine from the line before any serious damage results.

III. Influence of Hydrogen on the Design of Insulation

A few tests were made on the puncture voltages of sheet insulating material in air and hydrogen and no appreciable difference was found in the two cases, therefore no conclusion could be reached.

In order to obtain some information of the effect of hydrogen on the life of fibrous insulation, three samples of black varnish cloth were tested for 1300 hours under the conditions given below. The effect on the flexibility is given in the last column

Sample Number	Surrounding Medium	Temperature	Flexibility
1	H_2	100 deg. cent.	100
2	Air	100 deg. cent.	25
3	Air	25 deg. cent.	90

The samples were in the form of strips supported so that the air or hydrogen had free access to both sides. This condition is much more severe than that existing in insulation wound tightly on a coil, and protected by external coverings of varnish, but it gives results of value in forming conclusions as to the relative merits of the two gases in respect to the flexibility of the insulation. These tests of samples at about operating temperatures indicate that the life of insulation will be greater in hydrogen than in air as far as this life depends on brittleness of insulation.

The thickness of armature insulation for higher voltages is at present governed by the consideration of having a potential gradient that will not cause corona in minute spaces which may be present initially or developed later in the internal parts of the insulating material. The thickness necessary to withstand mechanical injury, high-potential tests, and the stresses of operation, are less than that required for the above consideration, and the removal of the more severe requirement first mentioned will allow a favorable decrease in thickness with the attendant benefits in design.

The thickness of field insulation is governed largely by the mechanical requirements of operation, but mechanical deterioration depends to a great extent on oxidation, and since this is not present in hydrogen, an increase in life may be confidently expected.

IV. Selection of the Most Suitable Hydrogen Pressure

If we neglect the question of leakage it surely would be a strange coincidence if it should be found that the most efficient pressure for hydrogen operation is at that of our surrounding atmosphere. To illustrate the properties which may be obtained in hydrogen under pressure, consider the case of ten atmospheres, or 147 lb. per sq. in. absolute.

1. The windage loss will be equal to that of the same machine in air.

2. The heat conductivity of a gas is independent of the pressure, and will therefore be the same as hydrogen at atmospheric pressure, which, as has been stated, is seven times as great as air.

3. The forced heat convection, or efficiency of heat removal by the high velocity gas flowing over the surface will be approximately thirteen times as great as for the air machine. This condition would render the surface temperature drops negligible, whereas in the air filled machine, the surface drops are considerable.

4. The dielectric strength of hydrogen, for one-cm. spacing at ten atmospheres pressure, will be approximately 60 per cent as strong as transil oil in bulk.

Thus a machine running in hydrogen at ten atmospheres pressure would approach many of the properties of an oil immersed machine and still have the same windage loss as an air cooled machine.

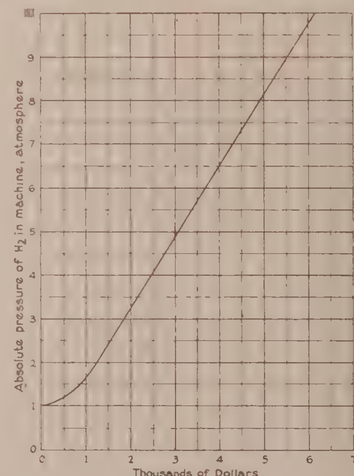

FIG. 4—YEARLY COST OF HYDROGEN LEAKAGE PER PIN HOLE AS A FUNCTION OF HYDROGEN PRESSURE

Fig. 4 shows the yearly cost of hydrogen leakage per pin hole of 0.025-cm. diameter (0.0005 sq. cm. area) as a function of the pressure of hydrogen in the machine. It will be noted that below a pressure of 1.9 atmospheres the curve is of a parabolic form and above that pressure it is a straight line. This difference is on account of the fact that the efflux of a gas is in conformity with one law up to a certain pressure and above that pressure it is in accordance with a different law, the point of transition being where the lower or outside pressure is 52.7 per cent of the higher pressure from which the gas escapes. At this point the velocity in the escaping jet is equal to the velocity of sound in the gas at atmospheric pressure and density or

$$V = \sqrt{\frac{\gamma P_0}{\rho}}$$

Where

V = velocity in cm. per sec.

γ = ratio of specific heat at constant pressure to that at constant volume

ρ = density of H_2 at the lower pressure in grams per c. c.

P_0 = External pressure in dynes per sq. cm. One atmosphere equals 1.0132×10^6 dynes per sq. cm.

At any pressure below 1.9 atmospheres, the transition point when the lower pressure is assumed to be one atmosphere, the amount of hydrogen passing through the orifice may be calculated from the following equation

$$W = 2.62\,A\sqrt{P\,\rho}\,\sqrt{\left(\frac{P_0}{P}\right)^{1.42} - \left(\frac{P_0}{P}\right)^{1.71}}$$

Where

W = gr. per sec.

A = area of orifice in sq. cm.

P = pressure of H_2 in machine in dynes per sq. cm.

ρ = density of H_2 in machine in gr. per c. c.

P_0 = external pressure in dynes per sq. cm.

For pressures above the point of transition the expression

$$W = 0.685\,A\,\sqrt{P\,\rho}$$

should be used.

In making calculations for the curve the area of the orifice was assumed to be as stated above, and the cost of hydrogen \$6.00 per kilogram, or approximately \$0.015 per cu. ft.

Derivations of the above equations are given by Lamb[8]. The determination of the most efficient pressure will depend on many design factors which are now unknown and therefore an estimate of the most suitable pressure, all things being considered, is impossible at the present time.

V. Tests of a Hydrogen Filled Machine

Object. Tests were made with a steam turbine type alternator operated as a synchronous motor to determine the capabilities of hydrogen as a cooling medium in a closed system of ventilation.

During the tests attention was directed primarily to the operating characteristics of the alternator which are inherent to the density, thermal conductivity, and convection of hydrogen. To emphasize these characteristics comparisons were obtained by making similar tests with air as a cooling agent.

While making these tests an opportunity was given to apply and observe the operation of protective devices, also to study some of the difficulties pertaining to the confinement of hydrogen under moderate pressures.

Description of Generator. A high-speed marine type alternator was selected for these tests, since it had fairly high windage losses, also because the outer shields which carried the armature were cast integral with the bearing supports, thus making a short closed circuit system of ventilation readily obtainable.

Ventilation System for Tests. Fig. 5 is a view of this generator arranged with closed circuit ventilating ducts, and coolers for removing the losses. The gas was discharged from the top of the stator frame into a sheet iron chamber, which was attached by gas tight joints to the discharge flange of the stator frame. The gas then divided and each half passed through two coolers, located near each end of the chamber from which the heat was removed by water. After passing through the coolers, the gas was drawn downward from the ends of the chamber through diverging sheet iron ducts over each end of the stator frame, thence into the generator through the fans on each end of the rotor.

Coolers and Rate of Heat Transmission. Since it was the purpose of these tests to determine the relative temperature rises of the windings, above that of the incoming cooling medium, little attention was given to the coolers other than to hold the water flow fairly constant.

The area of the cooling surface was 400 sq. ft., and the

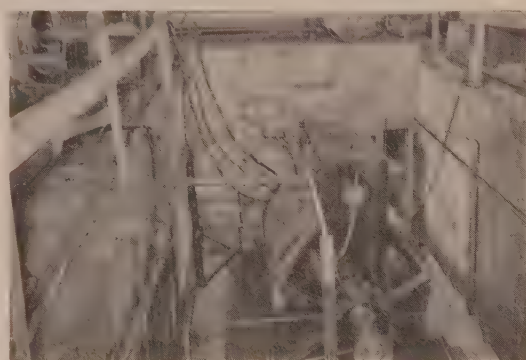

Fig. 5—Turbine Generator Arranged for Operation as a Synchronous Motor with Closed Circuit System of Ventilation Containing Hydrogen or Air as a Cooling Medium

net area of the air passages was 4 sq. ft. The velocity of water in the cooler tubes was 25, and the velocity of gas was 2100 ft. per min. Twenty-five gallons of water and 8400 cu. ft. of air were circulated per minute.

Although no accurate heat transfer tests were made on the coolers during operation it was found that they were much more effective with hydrogen than with air.

Protective Devices. Mechanical and electrical devices were used to detect explosive mixtures, automatically eliminate them, and prevent high pressures in case explosions should occur.

A small gasometer was connected to the point of lowest pressure in the machine, thereby maintaining a constant pressure slightly above that of the atmosphere, independent of temperature changes and leakage. Although leakage occurred on account of the crude joints between sheet iron and rough castings, the de-

8. Horace Lamb, Hydrodynamics, Cambridge University Press, 3rd. Edition, p. 23, 1906.

sired pressure was automatically maintained and contamination by air was prevented.

A recording device developed by C. Dansizen gave an accurate continuous log of the amount of impurity in the hydrogen. This device produced a graphic record of the difference in potential between the terminals of a pure metal filament placed inside the generator and through which a constant electrical current was automatically maintained. The resistance of the filament is a function of its temperature which depends upon the rate of heat transmission from the wire to the gaseous mixture, which, in turn, depends on the amount of impurity in the gas. With this apparatus a potential drop of 11.5 volts was observed with pure hydrogen and 12.5 volts with a mixture of hydrogen and one per cent of air impurity by volume.

Another safety device consisted of a metal filament, mounted upon a suitable support, placed within the generator and maintained at a temperature of from 700 deg. to 900 deg. cent. by means of an electric current. A mixture of air and hydrogen, having less than 15 per cent of air, will combine without explosion when brought in contact with the filament. The object of this device was to keep the air constantly being burned out of the hydrogen so that an explosive mixture could never be reached even though air should be continuously leaking into the machine.

Six diaphragms of varnished horn fiber ten inches in diameter and 15 mils thick were inserted in the outer walls of the ventilating ducts to relieve the pressure, in case the other devices were ignored or prevented from functioning and an explosion occurred.

Two diaphragms were so located that the gas impinged directly on their inner surfaces. It was feared that the varying force of the gas would cause sufficient movement of the diaphragms to produce failure if these were made of fiber. Lead diaphragms were used in these locations and they were cut nearly through their thickness so that their strength compared favorably with those made of fiber. The inertia of the lead prevented any destructive flutter.

Test Results. A duplicate machine had been operated in air at a load of 3380 kv-a. and at 3000 rev. per min. The losses under these conditions were

	Kw.	Per cent of Output	Per cent of Total Losses
Windage	35	1.48	38
Open Circuit Core Loss	27.5	1.16	30
$I_2 R$	13.25	.56	15
$I_2 R$ Loss of Rotor	16.1	.68	17
Total	91.85	3.88	100

From this tabulation of losses it is seen that a loss of 1.48 per cent of the capacity of the generator is produced by windage. It may be said in general that the windage loss in large steam turbine generators will fall between 1.00 and 1.75 per cent of the full-load capacity.

Unfortunately, conditions made it necessary to run the heating tests at 2400 instead of 3000 revolutions per minute, hence the windage loss was only 51 per cent of normal. This should be kept in mind when considering the results of the tests.

Heating Tests Using Air and Hydrogen for Cooling Agents. Four tests were made, the results of which are shown by Table II. These tests were made at no

TABLE 2

RESULTS OF TESTS WITH AIR AND HYDROGEN AS THE COOLING MEDIUM

Test Number	1	2	3	4
Duration of test hours	6	6.5	7.5	8
Cooling medium	Air	H_2	H_2	Air
Input to motor kv-a.	2400	3200	2400	2107
Armature current amps	750	1000	750	657
Armature voltage	1850	1850	1850	1850
Speed rev. per min.	2400	2400	2400	2400
Field current, amps	174	196.5	169.5	159.9
Field voltage at collector rings	114.2	129.6	100.5	98.7
Field input kw.	19.9	25.5	17.0	18.8
$I_2 R$ loss in stator winding kw.	10.9	19.5	9.9	8.0
Core loss kw.	19.	19.	19.	19.
Windage, kw.	17.9	1.8	1.8	17.9
Total loss in motor kw.	67.7	65.8	47.7	60.7
Temperature rise of rotor winding above average temperature of the ingoing cooling gas	79.	79.2	55.	62.
Maximum temp. rise of armature winding above average ingoing gas	39.	42.5	27.	31.1
Average temperature rise of six temp. detectors between coils of armature winding	35.9	28.2	23.9	28.7
Pressure of gas on suction side of fan inches of H_2O above atmosphere	—	1.	1.3	2.4
Temp. rise of field in deg. cent. per kw. of loss	3.79	3.10	3.23	3.49

load, using the alternator as a synchronous motor, with a value of field current to obtain the desired kv-a. input. Two of the tests, No. 1 and No. 3, were taken with 2400 kv-a. input, to determine the relative temperature rises of the rotor and stator windings using air and hydrogen.

Test 4 was made to determine approximately the reduced load necessary to secure the same temperature rise with air as was obtained with hydrogen in Test 3. Being unable to predict the temperature rises which would exist at the end of the run, the final temperatures in Test 4 were somewhat higher than in Test 3. By a comparison of runs No. 1 and No. 2 it will be seen that one-third more kv-a. were carried on the motor, with the same rise in temperature of the field winding, by using hydrogen instead of air as the cooling medium. The maximum temperature rise of the stator winding, as determined by resistance temperature detectors located between the top and bottom armature coils, was only 3.5 deg. cent. higher during the hydrogen run at 3200 kv-a. than with air during the 2400-kv-a. run.

Comparing tests No. 3 and No. 4; the final temperature rise of the field winding was 62 deg. cent., with air as the cooling agent during Test No. 4 at 2107 kv-a., whereas the rise obtained by Test No. 3 at 2400 kv-a. with hydrogen was only 55 deg. cent. Based upon the data secured during Tests No. 3 and No. 4 it is estimated that a load of closely 2700 kv-a. could have been carried when using hydrogen cooling with an

average temperature rise in the field winding of 62 deg. cent. This is 1.28 times the load of 2107 kv-a. carried when air was used as the cooling agent. It is doubtful whether the temperature rise of the armature at 2700 kv-a. cooled by hydrogen, would be more than 1 deg. or 2 deg. higher than the rise obtained at 2107 kv-a. when cooled by air.

The estimates of additional loads of 33 per cent and 28 per cent which have been made would be greater, if the tests had been made at the normal speed of 3000 instead of 2400 rev. per min.

VI. Heat Transfer from Rotor Winding

Having determined the increased cooling and rating permissible by the use of hydrogen in the small turbine-driven generator, an estimate was desired of the relative temperature rises which would be obtained by the embedded rotor copper in a large steam turbine driven alternator.

The temperature drops at heated surfaces cooled by forced convection of air and hydrogen were known, but no information was available by which an estimate could be made of the relative thermal drops from copper through the insulation to the sides of the rotor slots.

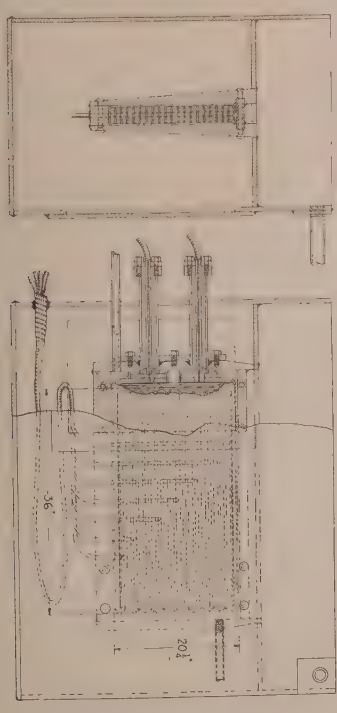

Fig. 6—Simulated Field Coil Arranged for Testing in Air and Hydrogen

To obtain this information, a coil having a resistance of 0.002 ohms at 25 deg. cent. was made of copper strip 0.875 in. by 0.03 in. in section, folded back and forth to obtain 20 layers in depth. The turns were separated from each other by layers of mica, and insulating armor 0.1 in. thick was moulded about the coil. This coil was actual size as regards the cross section but of course its length and shape differed from that of the coil which it represented.

The coil was enclosed in a retainer and seven thermocouples were soldered into the strips of the coil at different depths. The thermocouple leads were carried down through the coil and out of sealed holes in the steel bar at the bottom of the slot, see Fig. 6. As shown by the longitudinal and transverse sections, the coil container was welded into and hung from the edges of a rectangular slot in a steel plate. The coil, its container, and supporting plate were mounted in a steel box. Below the supporting plate the space about the container was lightly packed with silox, a silicon oxygen carbon compound of very low thermal conductivity. This caused practically all of the heat to pass to those surfaces of the container which corresponded to the surfaces exposed at the air gap of an actual machine. The heat was removed from these surfaces by water. The gas used for impregnating the coil was admitted and discharged through the end plates of the container. Gas pressure was maintained constant at 3¼ in. of water by means of a gasometer. The hydrogen used in these tests was analyzed and found to have the following composition by volume.

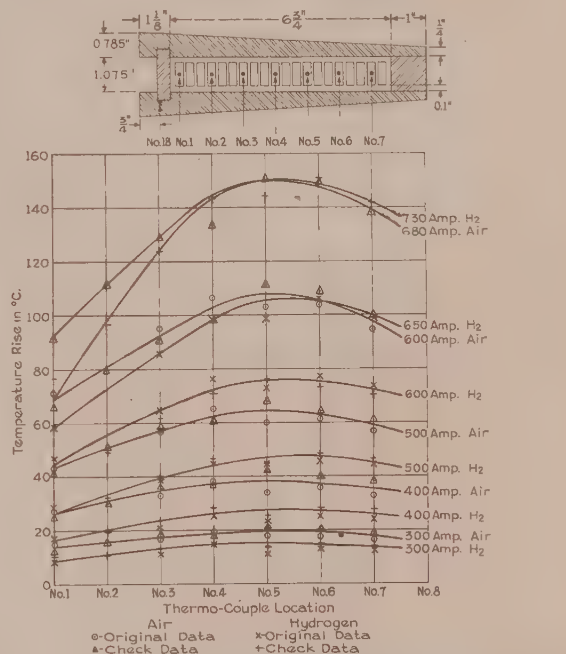

Fig. 7—Temperature Rise of Different Layers of Simulated Field Coil above Temperature at Location No. 18, when Cooled by Air and by Hydrogen

Carbon dioxide	0.4
Ethylene	Nil
Oxygene	1.0
Carbon Monoxide	0.2
Hydrogen	90.5
Methane	Nil
Nitrogen	7.9
	100.0

The gas used in this test did not contain as high a percentage of hydrogen as is present in the average commercial hydrogen.

Thermometers were placed in the water in contact with the face of the teeth, also on the water-cooled

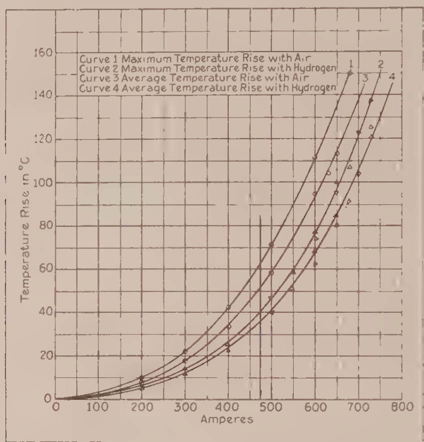

FIG. 8—TEMPERATURE RISE OF SIMULATED FIELD COIL WHEN COOLED BY AIR AND HYDROGEN

surface of the slot wedge. Three thermocouples were soldered to the bottom of ⅛-in. holes which were drilled ¾ in. below the water-cooled surface of the teeth. Their leads were protected from the water by small copper tubes soldered into the drilled holes.

The temperature rises were taken by resistance of the

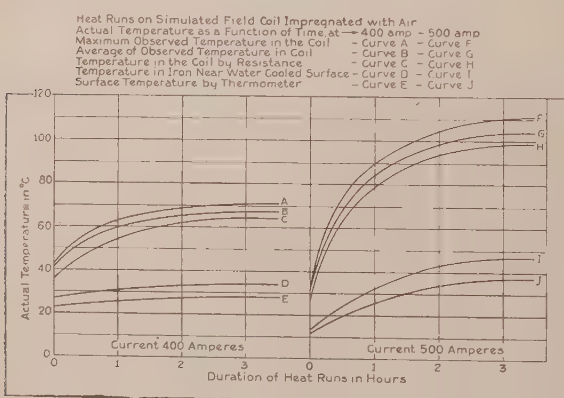

FIG. 9—RECORD OF TESTS ON SIMULATED FIELD COIL IN AIR WITH CURRENTS OF 400 AND 500 AMPERES

coil itself, and by the thermocouples in the turns of the coil. In Fig. 7 the temperature rises of the thermocouples are plotted above the temperature of No. 18 thermocouple, which was embedded near the face of the tooth. From an inspection of temperatures plotted in this figure it will be seen that the bottom strips of the coil did not attain the highest temperatures. Sixteen heat runs were made at different values of current, the maximum being 730 amperes, with coil impregnated with hydrogen.

The final maximum and average temperature rises, above that of the thermocouple embedded in the tooth face, are shown in Fig. 8 as a function of current. With 475 amperes, which is normal exciting current, both the average and maximum temperatures of the

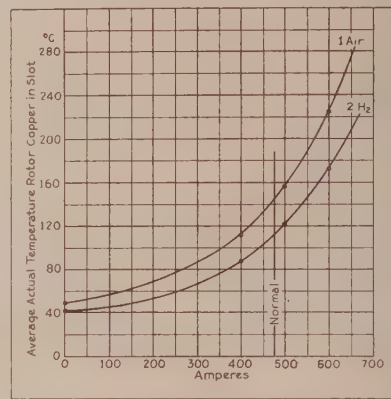

FIG. 10—ESTIMATED ACTUAL TEMPERATURES OF THE FIELD COIL OF A LARGE CAPACITY STEAM TURBINE-DRIVEN GENERATOR WHEN COOLED BY AIR AND HYDROGEN, INGOING GAS TEMPERATURE ASSUMED TO BE 40 DEG. CENT.

coil were about 35 per cent less with hydrogen than with air.

In Fig. 9 are shown the actual temperatures during

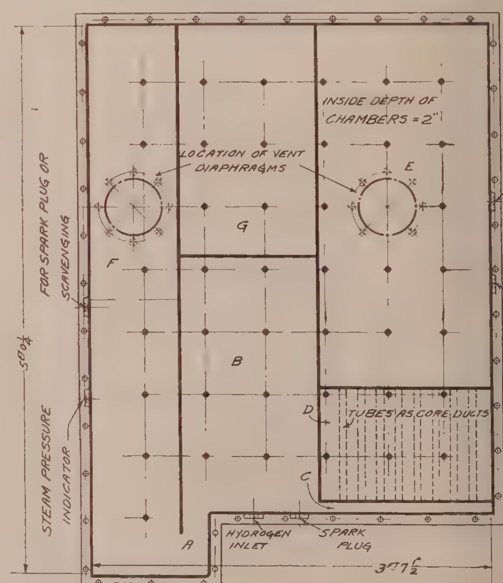

FIG. 11—MODEL OF GENERATOR CORE, FRAME, AND SHIELDS USED FOR EXPLOSION TESTS

A. Represents fan space
B. Represents end windings space
C. Represents air gap
D. Represents armature core
E. Represents armature frame space
F. Represents intake chamber
G. Represents connecting passage *E* to *F*

two heat runs at 400 and 500 amperes when the spaces were impregnated with air. Curves *D* and *I* refer to thermocouple No. 18 in Fig. 7. Curves *E* and *J* were

obtained by a thermometer located in the water close to the face of the tooth in which thermocouple No. 18 was placed. Referring to the final temperatures, the difference between D and E, and between I and J are 7 deg. and 10 deg. cent. respectively.

Table III gives the final maximum and average temperature rises, watts input, and watts dissipated per square inch of coil surface during a number of the heat runs with the coil impregnated by air and hydrogen.

This data was used to estimate the field temperature rises in air and hydrogen, of the machine whose field winding was simulated by the coil tested. See Fig. 10. The temperature of the medium entering the machine was assumed to be 40 deg. cent. It will be noted that at 0 amperes the temperature of the winding was 50 deg. for air and 41 deg. cent. for hydrogen cooling. These are the temperatures which would be attained by the field winding because of windage loss only. It will be seen that the temperature rises above the temperature of the medium entering the machine are 10 deg. and 1 deg. depending on which medium was assumed.

The normal exciting current was 475 amperes. Referring to Fig. 10, Curve *1*, it is seen that, at the current given, an actual temperature of 143 deg. cent. would be obtained in the embedded portion of the rotor body when cooled by air, whereas as shown by Curve *2*, the same load might be carried, when cooled by hydrogen, at an actual temperature of 110 deg. cent. This is a gain of 23 per cent. The armature temperature would be also be reduced in approximately the same ratio.

Capitalized otherwise, the field might be operated at 143 deg. cent. with an excitation of 550 amperes when hydrogen-cooled, which is sufficient to carry a load of 25 per cent more than normal. This does not take into account the lesser temperature drop at the surface of the cooler. With the increased load and reduction in windage loss the efficiency of the machine would be 1.2 per cent higher. These values agree closely with the results of the tests on the 3380-kv-a. machine mentioned in Section V.

VII. Explosions

The question most frequently asked the authors by those interested in this subject is in regard to explosions.[9]

9. A Study of Explosions in Gaseous Mixtures, by Kratz and Rosecrans, *Bulletin* 133, Engineering Experiment Station, University of Illinois.

In order to answer this question some preliminary tests were made by E. W. Kellogg. The apparatus consisted of an iron pipe 4 in. diameter by 24 in. long provided with a steam-engine indicator and spark plugs. The following maximum pressure rises were observed:

Gas Mixture by Volume	Maximum pressure lb. per sq. inch gage
20 per cent H_2 in Air	53
30 " " " " "	61
50 " " " " "	54
60 " " " " "	50
65 " " " " "	50

It was impossible to ignite mixtures containing more than about 65 per cent hydrogen. On the basis of heat content, an ideal mixture of hydrogen and air should produce a temperature of 4100 deg. cent. with a pressure of about 180 lb. per sq. inch gage. That such pressures are not obtained in practise is due to dissociation and the cooling effect of the enclosure. To test the effect of an explosion on insulation, small pieces of double cotton covered wire were placed in the bomb. Examination showed the outer layer of cotton to be scorched and slightly weakened. When the pressure was relieved by a paper vent, over the end of the bomb, no scorching was detected. It may be concluded, from these tests, that an explosion in a machine would have no detrimental effect on the insulation. To determine the feasibility of limiting the explosive pressure in a machine to moderate values by the use of suitably placed vents, the model shown in Fig. 11 was constructed. This represented as closely as convenient the various parts of the generator. The parts were full size except that the model was 2 in. thick in a direction normal to the surface of the page.

TABLE 3

TEMPERATURE DATA ON FIELD COIL

Gas in Coil	H_2	Air	H_2	Air	H_2	Air	H_2	Air	H_2	Air	H_2
Amperes	200	200	400	400	500	500	600	600	650	650	730
Watts input	81.2	82.0	360.0	377.6	612.5	647.5	972.0	1054.8	1200.0	1280.2	1636.0
Watts per sq. in. of coil surface	0.142	0.143	0.626	0.657	1.067	1.128	1.693	1.835	2.090	2.230	2.845
Max. temp. rise above thermocouple in Tooth face	5.9	8.4	25.6	37.9	46.2	64.7	77.3	106.4	100.1	126.1	138.5°C
Average temp. rise above thermocouple in Tooth face	4.6	7.3	22.5	33.4	40.9	57.7	68.7	95.8	85.3	113.2	120.8°C

The various spaces simulated were:

A—fan space

B—space around ends of winding

C—air gap

D—armature core and ducts

E—chamber encircling armature core

F—intake chamber

G—connecting passage from *E* to *F*

Pressures were measured by a steam-engine indicator started automatically just before the ignition of the gas. In general, the thicker the diaphragm the greater was the pressure developed by the explosion. As nearly as possible equal volumes of air and hydrogen were used but, in spite of the fact that the explosive range is considerably beyond this point in both direc-

tions, there were several times that the charge failed to explode, doubtless due to incomplete mixing. Twenty-five explosions were made and the highest recorded pressure (45 lb. per sq. in.) occurred when the venting diaphragms were replaced by steel plates.

There is no more reason to fear the explosion of a machine filled with hydrogen than that of other apparatus having considerable stored energy such as boilers, gas tanks, rotating elements, high-speed trains and automobiles, and various other familiar examples. Most of us fear a new condition if it has the possibility of accident, and accept as a matter of course the usual dangers of our daily lives.

VIII. Conclusions

To summarize previous statements, the advantages which may be realized in various proportions are, lower temperatures, greater capacity, lower losses, elimination of fire hazard, longer life, and greater reliability.

There seems to be no great difficulty or danger in the use of hydrogen in a properly designed and operated machine.

The automatic maintenance of hydrogen pressure slightly above atmosphere will prevent the ingress of air and the possibility of the explosive mixtures.

Several devices each operating on a different principle may be used to detect a change in the mixture and give an alarm long before the mixture reaches an explosive stage.

Finally, should all of these contrivances fail to operate and a spark be applied to an explosive mixture inside the machine the results would not be serious, since it is not difficult to vent the machine to reduce the force below a destructive value.

Grateful acknowledgment is made to Dr. W. R. Whitney and Dr. H. G. Reist for the keen interest which they have taken in the progress of the work.

A 132,000-VOLT UNDERGROUND CABLE FOR NEW YORK

New York City will, within the next year, be the scene of a notable advance in the transmission of electrical power and will have what unquestionably will be the most closely knit, most flexible, and thereby most efficient electrical generating and distributing system of any city in the world. This will come about as the result of the installation in the Bronx of an underground cable line which will be operated at 132,000 volts or twice the pressure of the highest-voltage underground cable line now used commercially anywhere in the world.

This new line will tie together the generating stations of The New York Edison Company and its allied companies, and thus bring the possibility of an interruption in the service of these companies practically to the irreducible minimum. Some idea of the importance of this accomplishment may be obtained when it is known that the fire department of the city relies on New York Edison service for the pumping of water and that any interruption in this service during a fire which would lower the pressure of the water available for the fire department would impose a penalty of $400 a minute on the company for the entire period during which the water pressure was inadequate. The new cable will make available 120,000 additional horse power of electricity to meet the ever-growing demand for power in this area.

Up to two years ago the highest pressures used in underground cables in America did not exceed 33,000 volts. In that year The New York Edison and its allied companies placed in service a new type of cable operating at 45,000 volts. Recently another company installed a 66,000-volt underground cable which is at present the highest-voltage line of its kind used commercially. While in the minds of some engineers there is still doubt about the practicability of using such high pressures in underground cables, The New York Edison Company, by ordering a cable of twice the present maximum pressure, has placed in the field of everyday practical affairs an electrical accomplishment which heretofore has been confined to the realm of speculation.

The engineering achievement involved in the installation of a 132,000-volt cable underground becomes apparent when it is known that to transmit power at such high voltage overhead would require the construction of steel towers of wind-mill construction, each the height of a seven story building, at intervals of 600 feet on the streets of the Bronx; it would be necessary to build at the top of these towers cross-arms carrying strings of nine or ten porcelain insulator disks, each string about six feet long and supporting a single wire; and there would be six such over-head wires. In place of this avenue of bulky steel structures, the new cable, which, with its insulation will be only three inches in diameter, will be placed in concrete ducts four or five feet below the surface of the ground.

The cable to be used for this purpose is known as the Pirelli type, and embodies in its construction the latest inventions in design of underground cables for very high pressures.

Because of the pioneering character of this installation and the ingenious methods of overcoming the engineering difficulties which the new problem presents, the installation of this cable will be watched with the greatest interest by electric public utilities in all sections of the country. It is probable that just as the first central station built by Thomas Alva Edison at Pearl Street, New York, became the forerunner of the vast electrical service industry of today, and just as the first steam turbines introduced by The New York Edison Company have become universally accepted as a means of producing electricity economically, so the lead of New York in high pressure underground electrical cables may lead to the use of such high powered underground cables, with their attendant advantages, throughout the country.

Separate Leakage Reactance of Transformer Windings

BY O. G. C. DAHL[1]

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Synopsis.—The paper discusses a method for determining the separate leakage reactances of transformer windings, originally suggested in 1921 by W. V. Lyon.[2] *The method is applicable only to three-phase banks of three identical transformers, and makes use of the third harmonic electromotive force and current which are introduced into the windings by the inherent magnetizing characteristics of the iron. Attempts made to determine the separate leakage reactances of a single transformer did not meet with success.*

The method may be used both with "two-winding" and "multi-winding" transformers. However, it is particularly convenient when the transformers have more than two windings.

Laboratory tests have been made on small experimental, two-winding and three-winding transformers, and field tests on a bank of three-winding power transformers. The results in each case warrant the conclusion that the separate leakage reactances may be obtained with sufficient accuracy for engineering purposes.

Introduction

THE separate leakage reactances of transformer windings cannot be calculated with accuracy. The standard formulas found in textbooks on principles and design of transformers are all based on broad assumptions in regard to the distribution of the leakage flux, and may easily give results which are in error to a considerable extent. Furthermore, it seems to be doubtful whether more rigorous and reliable formulas are capable of being developed.

So far, no method has been available for experimental determination of the individual leakage reactances. It is easy to obtain the equivalent leakage reactance by a short-circuit test, but when it comes to assigning proper fractions of this reactance to the separate windings, difficulties are encountered. Usually the equivalent reactance is split equally between the two windings. This procedure, however, is frequently far from correct although often the only one which can be resorted to.

The purpose of this paper is to present a method, originally suggested in 1921 by W. V. Lyon,[2] by which the separate leakage reactances of transformer windings may be determined experimentally. This work was done as an introduction to a general study of transformer harmonics undertaken in the Electrical Research Laboratories of the Massachusetts Institute of Technology.[3]

The theory of the method is briefly discussed and data and results as obtained from tests on three small experimental transformers are given.

The method has also, with success, been applied to a bank of three 2100-kv-a., 110,000/22,000/2300-volt transformers.[4]

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2. Massachusetts Institute of Technology.

3. Some results of these researches have been incorporated in the author's report "Transformer Harmonics" published in the report of the Inductive Coordination Committee of the National Electric Light Association in June 1923.

4. See the paper "Transformer Harmonics and Their Distribution."

Presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

Conception of Leakage Reactances

The mutual flux in an iron-core transformer is usually considered to be exclusively confined to the core. This assumption is not entirely rigorous. Evidently part of the flux which the current in any one coil sets up in the air will produce linkages with the other coils and hence be a mutual flux in the true sense of the word.

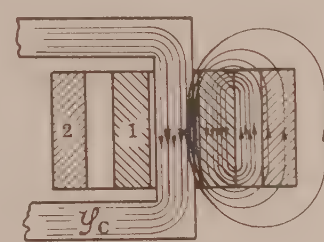


Fig. 1—Flux Distribution (Very Approximate) When the Inner Coil (1) Carries Current

All fluxes which have their entire path in air are proportional to the current producing them. This is true also for fluxes which only partly exist in the air, since the reluctance of the iron path is insignificant as compared to the reluctance of the air path.

Fig. 1 roughly illustrates the fluxes when the inner coil (1) carries current. As seen, a small part of the

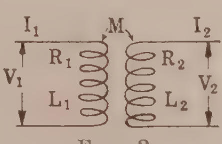


Fig. 2

flux set up in the air will link with turns of coil (2) and produce a voltage in this coil in addition to the voltage produced by the flux in the core. This additional voltage will be in time quadrature with the current in coil (1).

Fig. 2 represents a two-winding transformer with both windings carrying current. Considering voltages and currents of a *single frequency* only the vector

equations for the voltage drops in the two windings may be written:

$$V_1 = R_1 I_1 + j\,\omega\,L_1 I_1 + j\,\omega\,M_{12} I_2 \qquad (1)$$

$$V_2 = R_2 I_2 + j\,\omega\,L_2 I_2 + j\,\omega\,M_{21} I_1 \qquad (2)$$

Since the permeability of the iron is a function of the instantaneous flux density and hence of the instantaneous current, the self and mutual inductances will be some function of the current. On the contrary, the inductances which are due to fluxes in the air will be constant.

The flux in the core itself contributes the part, M_c, of the mutual inductance. Introducing this quantity, the two equations above may be rewritten in the following form:

$$V_1 = R_1 I_1 + j\,\omega\,(L_1 - M_c)\,I_1 + j\,\omega\,(M_{12} - M_c)\,I_2 + j\,\omega\,M_c\,(I_1 + I_2) \qquad (3)$$

$$V_2 = R_2 I_2 + j\,\omega\,(L_2 - M_c)\,I_2 + j\,\omega\,(M_{21} - M_c)\,I_1 + j\,\omega\,M_c\,(I_1 + I_2) \qquad (4)$$

In equation (3), $L_1 - M_c$ is a *constant* inductance due to all the flux in the air set up by the current in coil (1). It is the "self leakage inductance" of this coil. $M_{12} - M_c$ is the constant "mutual leakage inductance" of coil (1). The term $j\,\omega\,M_c\,(I_1 + I_2)$ evidently represents the voltage induced in coil (1) by the flux which exclusively exists in the core. The corresponding quantities in equation (4) may be similarly interpreted with reference to coil (2).

Introducing

$$X_{11} = \omega\,(L_1 - M_c) \qquad (5)$$

$$X_{22} = \omega\,(L_2 - M_c) \qquad (6)$$

$$X_{12} = X_{21} = \omega\,(M_{12} - M_c) = \omega\,(M_{21} - M_c) \qquad (7)$$

$$E_{1c} = E_{2c} = j\,\omega\,M_c\,(I_1 + I_2) \qquad (8)$$

equations (3) and (4) reduce to

$$V_1 = E_{1c} + (R_1 + j\,\omega\,X_{11})\,I_1 + j\,\omega\,X_{12} I_2 \qquad (9)$$

$$V_2 = E_{2c} + (R_2 + j\,\omega\,X_{22})\,I_2 + j\,\omega\,X_{21} I_1 \qquad (10)$$

Neglecting the exciting current, the primary and secondary currents are equal and opposite and the equivalent impedance drop $V_1 - V_2$ becomes

$$\begin{aligned} V_1 - V_2 &= [R_1 + j(X_{11} - X_{12})]\,I_1 - [R_2 + j\,(X_{22} - X_{21})]\,I_2 \\ &= (R_1 + j\,X_1)\,I_1 - (R_2 + j\,X_2)\,I_2 \\ &= [\,R_1 + R_2 + j\,(X_1 + X_2)\,]\,I_1 \\ &= (R_e + j\,X_e)\,I_1 \end{aligned} \qquad (11)$$

The reactances, X_1 and X_2, are the true leakage reactances of windings (1) and (2), respectively, with respect to the other winding. The relative aspect of the leakage reactances should be carefully noted. The leakage reactance of a winding is not a quantity which is dependent upon and characteristic of that winding alone; it must, of necessity, be defined with respect to some other winding. This fact becomes particularly important in multi-winding transformers. Thus in a transformer having three windings designated Nos. 1, 2 and 3, the leakage reactance of winding No. 1 with respect to winding No. 2 will be in general different from the leakage reactance of the same winding with respect to winding No. 3.

In the following the true leakage reactance will be termed the leakage reactance and the mutual leakage reactance will be called the mutual reactance.

The relative magnitude of the leakage and the mutual reactance of a winding depends upon the spacing and arrangement of the coils. If the spacing is large the mutual reactance is small and in some cases may even become negligible.

The standard short-circuit test gives the equivalent leakage impedance of any two windings of a transformer. Equation (11) expresses short-circuit conditions when V_2 is zero. Fig. 3 shows the vector diagram of a short-circuited transformer, the exciting current being neglected and the primary vectors being rotated through 180 deg. Both leakage reactance drops and mutual reactance drops are indicated on the diagram.

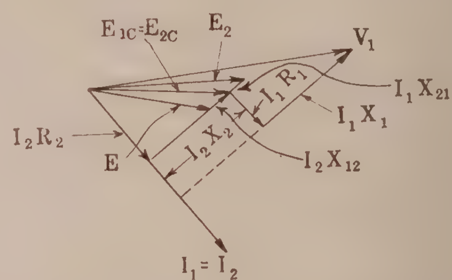


FIG. 3—VECTOR DIAGRAM OF A SHORT-CIRCUITED TRANSFORMER, SHOWING RESISTANCE, LEAKAGE REACTANCE AND MUTUAL REACTANCE DROPS

EXPERIMENTAL DETERMINATION OF SEPARATE LEAKAGE REACTANCES

a. General. The experimental method by which the separate leakage reactance of the windings of a transformer may be determined makes use of the third harmonic component which inherently exists in the magnetizing current of a transformer when a sinusoidal voltage is impressed. The method is applicable only when a three-phase bank of three identical transformers is available. Attempts made to determine the leakage reactance of a single transformer did not meet with success.

The principle of the method is as follows: If sinusoidal voltages are impressed on a Y-Δ-connected bank of transformers, the third harmonic component of the magnetizing current will be confined to the delta where it appears as a circulating current. If the transformers are perfectly balanced and there is no external load on the secondary, no current other than the third harmonic and its multiples can exist in the delta. Usually the ninth and fifteenth harmonics, etc., are negligible and need not be considered. The third harmonic electromotive force induced per phase of the delta is just balanced by the triple frequency impedance drop due to the circulatory third harmonic current. The problem is then to measure with precision the proper

third harmonic electromotive force and current, which, by simple division, will give the desired triple frequency leakage impedance.

b. Two-winding Transformers. The bank is connected Y-Δ and balanced sinusoidal voltages impressed. The third harmonic current in the delta and the third harmonic electromotive force per phase on the primary side are recorded. The latter is most practically ob-

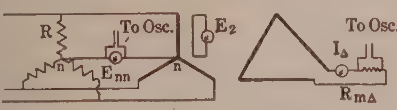


Fig. 4—Diagram of Connections for Leakage Impedance Test on Two-Winding Transformer

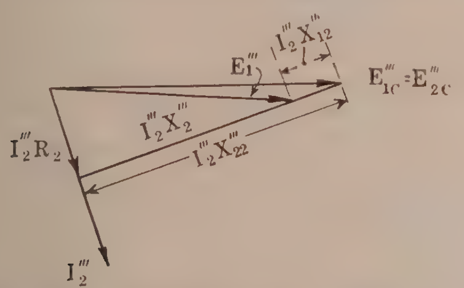


Fig. 5—Vector Diagram of Third Harmonic Quantities Involved in the "Two-Winding Method"

tained by connecting a Y-connected resistor bank between the lines and measuring the voltage between the resistor and transformer neutrals.

If the generator is Y-connected and its phase voltage is free from a third harmonic (and multiples), the bank of resistors may be omitted and the voltage measured between generator and transformer neutrals. No commercial Y-connected generator, however, is entirely without a third harmonic component in its voltage to neutral, so this method is scarcely of practical interest.

As a rule, it will be necessary to take oscillographic records and separate out the third harmonics by analysis. While the current in the delta is sensibly third harmonic, a fundamental and also other harmonics are unavoidable between the two neutrals, if even the slightest unbalance in the impressed voltages, the resistors or the transformers themselves is present.

The diagram of connections and the third harmonic vector diagram are given in Fig. 4 and Fig. 5, respectively. One to one ratio of transformation is assumed. If the transformers have another ratio, the quantities in the various equations given below should all be referred to the same side.

If R is the resistance of the resistors per phase, r the resistance of the voltmeter and E_{nn}''' the third harmonic voltage between the neutrals, then

$$E_1''' = E_{nn}''' \left(1 + \frac{R}{3\,r}\right) \qquad (12)$$

This voltage is the vector sum of two components. One component (E_{c1}''') is induced in each primary winding by the triple frequency flux (ϕ_c''') in the core. The second component ($-j\,X_{12}'''\,I_2'''$) is induced by the part of the third harmonic flux in the air which produces linkages with the primary winding. Hence from equation (**10**), considering voltage rises;

$$E_1''' = E_{1c}''' - j\,X_{12}'''\,I_2''' = E_{2c}''' - j\,X_{12}'''\,I_2''' \qquad (13)$$

The triple frequency leakage impedance and reactance of the secondary windings are now found by

$$Z_2''' = \frac{E_1'''}{I_2'''} \qquad (14)$$

$$X_2''' = \sqrt{(Z_2''')^2 - (R_2)^2} \qquad (15)$$

This X_2''' is a *true triple frequency leakage reactance.* By repeating the measurements with the original primary winding as secondary and vice versa, the leakage reactance of the other winding may be found in a similar manner. Dividing the triple frequency reactances by three, the fundamental reactances are found.

Having determined the individual leakage reactances, the equivalent impedance of the transformer becomes (1 to 1 ratio assumed):

$$Z_e' = \sqrt{(R_1 + R_2)^2 + (X_1' + X_2')^2} \qquad (16)$$

This value should, if correct, check the short-circuit impedance of the transformer to at least engineering accuracy.

c. Three-winding Transformers. When the transformers have more than two windings, a more convenient method may be used which eliminates the necessity of establishing the artificial neutral on the primary side. As before, the primaries are Y-connected, while the other two windings are Δ-connected. One

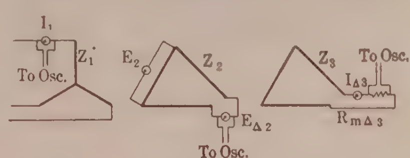


Fig. 6—Diagram of Connections for Leakage Impedance Test on Three-Winding Transformer

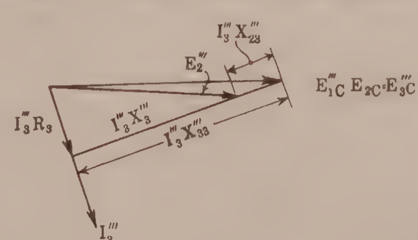


Fig. 7—Vector Diagram of Third Harmonic Quantities Involved in the "Three-Winding Method"

delta is closed and the circulating third harmonic current in it recorded. The other delta is not closed; the third harmonic voltage appearing across the open corner of this delta may therefore be measured and will for balanced conditions be equal to three times the third harmonic electromotive force per phase. Recording these two quantities makes it possible to determine the leakage reactance of the closed delta winding

with respect to the open delta winding. In many cases oscillographic records are unnecessary when the transformers are well balanced, as both the voltage and the current will be sensibly third harmonic.

The connections are shown in Fig. 6 and the third harmonic vector diagram in Fig. 7.

Solution of the vector diagram exactly as in the preceding case gives the leakage reactance of winding No. 3 with respect to winding No. 2. By repeating the measurements with changed connections, the other individual reactances are obtained.

It is beyond the scope of this paper to discuss how the separate leakage impedances in a three-winding transformer may be combined for the purpose of calculating load division, etc., between the various windings when they all carry currents.

Experimental Work

a. Apparatus. Fig. 8 shows one of the test transformers used for the experimental work in the Electrical Research Laboratories of the Massachusetts Institute of Technology. Three transformers of this type were used, the approximate rating of each being two kw.

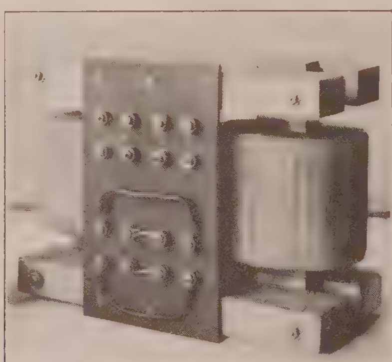


Fig. 8—Core-Type Experimental Transformer Used in the Tests at the Massachusetts Institute of Technology

The cores, built up of silicon steel laminations with lap joints, are firmly held together by wooden frames with through-going brass bolts. The dimensions of each lamination are 8 in. by $1\frac{1}{2}$ in. by 0.014 in. The gross thickness of the cores is 2 in., giving a gross cross-sectional area of 3 sq. in. (19.36 sq. cm.). Assuming 95 per cent lamination factor, the net area becomes 2.85 sq. in. (18.4 sq. cm.).

There are four coils on each leg, numbered 1, 2, 3 and 4, in the order of their proximity to the core. Each coil consists of 100 turns, double cotton covered copper wire, wound in two layers with the thickness of the insulation only between layers. Coils No. 1 and No. 2 are wound with No. 12 B. & S. wire and are separated by the thickness of the insulation only. Coil No. 3, also of No. 12 wire, is spaced $\frac{3}{4}$ in. from coil No. 2, beind supported by square wooden spacers. Coil No. 3 has wound with it a search coil of No. 24 wire, which is designated as coil No. 4.

Both ends of each coil are brought out to binding posts on a fibre terminal board. During most of the tests the corresponding coils on the two legs were connected in series, forming windings of 200 turns.

The transformers were well balanced electrically. This is apparent from Fig. 9, which shows curves of the exciting currents of the three units as obtained from single-phase tests with a sinusoidal voltage impressed.

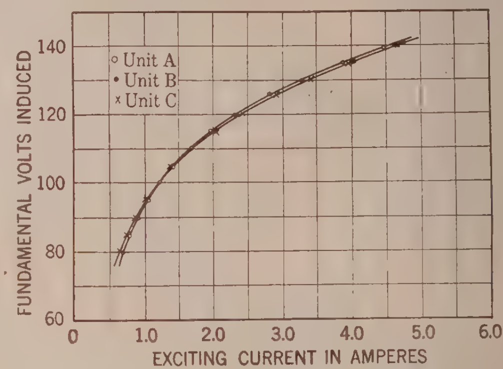


Fig. 9—Single-Phase Exciting Current of the Experimental Transformers. The Curves Show that the Transformers Were Well Balanced Electrically

As source of power a three-phase, 60-cycle, 5-kw., 230-115-volt sine-wave generator was used. This generator gave a very staisfactory wave shape at all balanced loads.

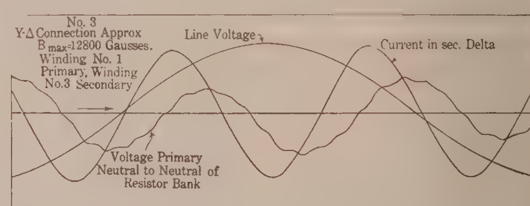


Fig. 10—Oscillogram from Leakage Impedance Test on Two-Winding Transformer. Circuit Connections Shown in Fig. 4.

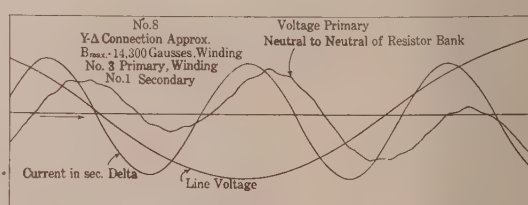


Fig. 11—Oscillogram from Leakage Impedance Test on Two-Winding Transformer. Circuit Connections Shown in Fig. 4

Vacuum thermocouples were used for the measurements whenever it was necessary to record voltages without drawing appreciable current, and also in order to measure currents in circuits where commercial ammeters would cause serious disturbance in existing conditions. Either shunt or series resistance was

used in the heater circuit in order to adapt the thermocouple to any desired range. A microammeter was used as indicator in the circuit of the thermo-element.

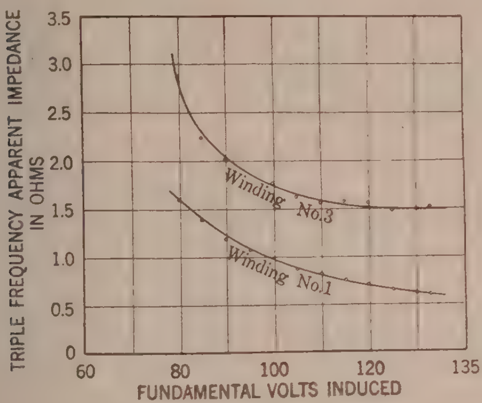


FIG. 12—THE CURVES SHOW THE "APPARENT" LEAKAGE IMPEDANCE AS OBTAINED FROM METER READINGS ALONE USING THE CONNECTIONS SHOWN IN FIG. 4. THE "APPARENT" VARIATION WITH SATURATION IS MAINLY DUE TO A PRONOUNCED FUNDAMENTAL VOLTAGE OF VARYING MAGNITUDE IN ADDITION TO THE THIRD HARMONIC BETWEEN THE TRANSFORMER AND RESISTOR NEUTRALS. HENCE IT IS IN GENERAL NECESSARY TO TAKE OSCILLOGRAPHIC RECORDS WHEN ARTIFICIAL PRIMARY NEUTRAL IS USED.

b. Test Results.[5] Figs. 10 and 11 show two a of series of oscillograms when the "two-winding" test was applied to the experimental transformers. Fig. 10 was taken while the winding designated No. 1 was used as primary, winding No. 3 being secondary. In Fig. 11, winding No. 3 was primary, No. 1 secondary. The spacing between these two windings is large enough so as to make the mutual effect of the air fluxes small.

The necessity of using oscillographic records when this connection with artificial neutral on the primary side is used is best illustrated by the curves (Fig. 12) which give the triple frequency leakage impedance of coil No. 1 and coil No. 3 as computed directly from meter readings. According to these curves the leakage impedances apparently vary with the saturation, which in reality is not the case. The apparent variation is mainly due to a pronounced fundamental voltage of varying magnitude in addition to the third harmonic between the transformer and resistor neutrals (See Figs. 10 and 11).

Tables I and II give the data and results from this test performed at four values of flux density. The oscillograms were analyzed for their third harmonic

5. Part of the given experimental data were recorded by W. J. Miller, formerly of the Massachusetts Institute of Technology.

TABLE I

Connections	Oscillogram No.	Approx. flux density (Gausses)	Volts induced in winding No. 2			Amperes in delta I_Δ	Volts between neutrals E_{nn}	Ohms Resistance in metering circuit $R_{m\Delta}$
			Unit A	Unit B	Unit C			
Windings No. 1 primary Y; No. 3 secondary Δ	1	9200	90.0	90.0	89.0	0.339	0.645	1.34
	2	11200	110.0	110.0	109.0	0.670	1.120	1.25
	3	12800	125.0	125.0	124.3	1.270	1.980	1.14
	4	14300	140.0	140.0	139.3	2.470	3.885	0.89
Windings No. 3 primary Y; No. 1 secondary Δ	5	9200	90.0	90.0	89.0	0.330	0.972	1.45
	6	11200	110.0	110.0	109.3	0.710	1.240	1.25
	7	12800	125.0	125.0	124.0	1.330	1.620	1.25
	8	14300	140.0	140.0	139.0	2.670	2.300	1.00

TABLE II

Connections	Oscillogram No.	Third harmonic e. m. f. per phase E'''	Third harmonic current in delta I_Δ'''	Total third harmonic impedance per phase of delta Z_t'''	Resistance of delta winding per phase R	Total resistance per phase of delta R_t	Third harmonic reactance per phase of delta X'''	Average third harmonic reactance X'''
Windings No. 1 primary Y; No. 3 secondary Δ.	1	0.521	0.339	1.537	0.466	0.913	1.235	
	2	1.023	0.670	1.530	0.466	0.883	1.249	
	3	1.922	1.270	1.513	0.466	0.846	1.254	
	4	3.855	2.470	1.560	0.466	0.763	1.360	1.275
Windings No. 3 primary Y; No. 1 secondary Δ.	5	0.282	0.329	0.858	0.284	0.767	0.384	
	6	0.598	0.710	0.842	0.284	0.701	0.466	
	7	1.085	1.330	0.816	0.284	0.701	0.417	
	8	1.970	2.660	0.741	0.284	0.617	0.410	0.414

components, the current waves by the 5-ordinate, and the voltage by the 11-ordinate schedule method. It will be noticed, however, that the current, without appreciable error, might have been taken directly from the meter readings since it appears to be practically third harmonic. Inspection shows that the maximum difference between any single value of the third harmonic leakage reactance and the average is about 10 per cent.

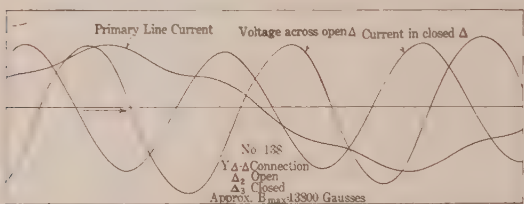


FIG. 13—OSCILLOGRAM FROM LEAKAGE IMPEDANCE ON THREE-WINDING TRANSFORMER. CIRCUIT CONNECTIONS SHOWN IN FIG. 6.

The leakage reactance of winding No. 3 was also found by the "three-winding method." Fig. 13 shows one of the oscillograms, while Table III gives the data and results from this test, which also was performed at four densities. It will be noted that the test gives the neutral point on the primary side. The four values of the leakage impedance are practically coinciding.

The value of the triple frequency leakage reactance of winding No. 3 from this test, is 1.336 ohms as compared with 1.275 ohms from the other test. The difference between the two is about 4½ per cent.

Since more consistent results are obtained in this test, the larger value of X_3''' is assumed to be the better one. Using then

$$X_1''' = 0.414 \text{ ohm}$$
$$X_3''' = 1.336 \text{ ohms}$$

the fundamental reactances become

$$X_1' = 0.138 \text{ ohm}$$
$$X_3' = 0.445 \text{ ohm}$$

The average short-circuited impedance of windings No. 1 and No. 3 obtained from a series of short-circuit tests on all transformers is 1.023 ohms, and the ohmic resistances, measured directly after the short-circuit tests, are 0.308 ohm and 0.513 ohm for windings No. 1 and No. 3 respectively. It will be noticed that these resistances are slightly larger than those used in the tables. This, of course, is due to the fact that the transformers became heated during the short-circuit tests, while the current during the other tests was entirely too small to cause any appreciable temperature rise.

TABLE III

Connections	Oscillogram Number	Approx. flux density Gausses	Volts induced in winding No. 2 E_2	Volts across open delta $E_{\Delta 2}$	Amperes in closed delta $I_{\Delta 3}$	Ohms impedance $\frac{E_{\Delta 2}}{3\,I_{\Delta 3}}$	Ohms resistance in metering circuit $R_{m\Delta 3}$	Third harmonic volts across open delta $E_{\Delta 2}'''$	Third harmonic amperes in closed delta $I_{\Delta 3}'''$	Ohms impedance $\frac{E_{\Delta 2}'''}{3\,I_{\Delta 3}'''}$
Winding No. 1 primary Y, No. 2 open Δ, No. 3 closed Δ	137	13100	128.0	6.10	1.310	1.552	0.66	5.88	1.308	1.500
	138	13800	135.0	8.32	1.785	1.554	0.66	8.02	1.781	1.501
	139	12300	121.0	4.60	0.987	1.553	0.66	4.43	0.984	1.502
	140	11300	111.0	3.22	0.691	1.554	0.66	3.10	0.689	1.500

Average $\frac{E_{\Delta 2}}{3\,I_{\Delta 3}}$ = 1.553 ohms Average $\frac{E_{\Delta 2}'''}{3\,I_{\Delta 3}'''}$ = 1.501 ohms Discrepancy = 3.46 per cent.

Average $X_3''' = \sqrt{(1.501)^2 - (0.466 + 0.66)^2} = 1.336$ ohms

leakage reactance of winding No. 3 with respect to winding No. 2. Windings No. 1 and No. 2, however, were so close together that the leakage between them was entirely negligible; hence the leakage reactance of winding No. 3, with respect to winding No. 2, coincides with the leakage reactance of winding No. 3 with respect to winding No. 1.

As seen from the oscillogram, the current in delta No. 3 is practically a pure third harmonic, while the voltage across the open corner of delta No. 2 is very nearly third harmonic. It appears from Table III that the discrepancy between results obtained from wave analyses and those obtained directly from meter readings is only about 3½ per cent.

It will also be noted that this method gives much more consistent results than the Y-Δ method with artificial

Using the individual reactances in connection with the hot resistances gives for the equivalent impedance:

$$Z_e' = \sqrt{(0.308+0.513)^2 + (0.138+0.445)^2} = 1.007 \text{ ohm}$$

The discrepancy between the two equivalent impedances is

$$\frac{1.023 - 1.007}{1.023}\,100 = 1.56 \text{ per cent}$$

SUMMARY

The paper has presented a method for experimental determination of separate leakage reactances of transformer windings. It is applicable only to three-phase banks of identical transformers and is based on simultaneous measurements of a third harmonic current and the third harmonic electromotive force producing it.

The method can be used both with two-winding and multi-winding transformers. It is particularly convenient, however, when the transformers have more than two windings since the necessity of establishing an artificial neutral point on the primary side is eliminated. Furthermore, oscillographic records are less important in this case due to the fact that the quantities measured are very nearly of triple frequency when the transformers are well balanced. Meter readings alone will therefore often be sufficient.

The experimental data from the tests in the Electrical Research Laboratories of the Massachusetts Institute of Technology, which have been reproduced, show that the obtained results are consistent and accurate enough for engineering purposes. This was also substantiated by the field tests previously referred to on the bank of three 2100-kv-a., 110,000/22,000/2300-volt transformers.

LIST OF SYMBOLS

V = Terminal voltage
E = Induced voltage
E_c = Voltage induced by flux in the core
E_Δ = Voltage across the corner of an open delta winding
I = Current
I_Δ = Circulatory current in a closed delta winding
ϕ_c = Flux exclusively confined to the core
$R_{m\Delta}$ = resistance in the corner of a closed delta winding

Subscripts attached to the above symbols refer the quantities to the particular winding designated by the subscript.

E_{nn} = Voltage between resistor and transformer neutrals
R = Resistance of resistors per phase
r = Resistance of voltmeter
R_1, R_2 = Resistance of windings No. 1 and No. 2
L_1, L_2 = Self-inductance of windings No. 1 and No. 2
$M_{12} = M_{21}$ = Mutual inductance between windings No. 1 and No. 2
M_c = Mutual inductance due to flux in the core
X_{11}, X_{22} = Self-reactance of windings No. 1 and No. 2
$X_{12} = X_{21}$ = Mutual reactance of windings No. 1 and No. 2
X_1, X_2 = Leakage reactance of windings No. 1 and No. 2 with respect to some specified winding
R_e = Equivalent resistance of two windings
X_e = Equivalent reactance of two windings
$\omega = 2\pi f$ = Angular velocity

Several of the above quantities are different for the various harmonics. Primes attached to these quantities indicate the order of the harmonic.

Law Description and Hypothesis in the Electrical Science[1]

BY M. I. PUPIN[2]

YOUR invitation to deliver the first Steinmetz lecture I consider a very great honor. The late Doctor Steinmetz was a dear friend of mine. I met him in Yonkers in 1889, and from that time on until his death we were tied to each other by bonds of personal sympathy and scientific interest, which was a source of uninterrupted pleasure to both of us.

This lecture is an attempt to describe briefly how Faraday and Maxwell, starting from definite laws which were discovered by experiment, created the modern Electromagnetic Theory by a prophetic use of description and hypothesis, and how this theory furnishes the foundation of the Science of Electrical Engineering.

Our knowledge of electrical phenomena began its career as a science when it started to build upon a foundation of a quantitative law. Coulomb's law marks, therefore, the beginning of the electrical science. It says that two electrical point charges in a vacuum act upon each other with a mechanical force which is equal to the product of the two charges divided by the square of the distance between them.

In its mathematical form Coulomb's law is identical with Newton's law of gravitational action. Many theorems which the mathematical physicists of the eighteenth and the beginning of the nineteenth century had developed in their analysis of gravitational fields of force were, apparently, directly applicable to the analysis of electrical fields. This was very fortunate, because it attracted some of the best mathematical minds of those days to the electrical science. This raised its standing among the sciences which it badly needed.

Newton's great essay, Principia Philosophiae Naturalis, published in the beginning of the eighteenth century, created a new school of natural philosophers

1. The first Steinmetz lecture delivered on May 8, 1925, before the Schenectady section of the American Institute of Electrical Engineers.

2. Of Columbia University, New York.

which dominated during the eighteenth century the scientific mental attitude of the world. No natural philosopher of those days could expect to attract serious attention who departed from the rigorously mathematical methods of this school. Even so great a natural philosopher as Benjamin Franklin may be said to have been snubbed by the Royal Society, when it refused to publish in its transactions Franklin's communications describing his electrical experiments. These experiments, suggested by and clustering around Leyden jar discharges, had no obvious connection with the Newtonian school of natural philosophy of the eighteenth century and, therefore, the Royal Society failed to recognize their full significance. One may imagine how welcome Coulomb's law was to some natural philosophers of the eighteenth century, to whom Newton's Principia was as final as the book of Genesis is to some people of our own generation.

Faraday was the first to point out a fundamental difference between Newton's law of gravitational action and Coulomb's law of electrical action. The action of a gravitational mass upon another gravitational mass is not influenced by the medium separating the two, but the action of an electrical charge upon another electrical charge is influenced very much by the medium separating the two. Coulomb's law unaided by other considerations was unable to explain this difference. Faraday was the first to enter into these considerations, and his first guide may be said to have been a hypothesis which maintained that all electrical charges trace their origin to the molecules and atoms of material bodies, which in their normal state contain, according to Franklin, the same amounts of positive and negative charges. This hypothesis of the atomic origin of electrical charges was undoubtedly suggested by Faraday's classical studies of the behavior of electrolytes, which revealed a new truth, namely, that a definite electrical charge is attached to each valency of atoms. The granular structure of ordinary electrical charges and the whole modern electron theory was first foreshadowed in these experiments. But how did this hypothesis affect Coulomb's law of force between Coulomb charges which are located in a material medium?

Consider the insulators. The hypothesis suggested that in an insulator each molecule contains a definite quantity of positive and an equal quantity of negative charge which can be separated from each other by the action of an external electrical force impressed upon them, but that the distance of separation cannot exceed the dimensions of the molecule. Adopting this picture of the electrical structure and behavior of insulators there was readily deduced a modified form of Coulomb's law of force between charges separated by an insulating medium, and this modified form of Coulomb's law says: *The force between two point charges in an insulating material medium is equal to that in a vacuum divided by a constant, called the specific inductive capacity of the material medium.* But experiment told us that the hypothesis mentioned above concerning the process of separating molecular charges and everything inferred from it can be only approximately true, because the specific inductive capacity of material insulators is usually neither constant nor does it always have a definite meaning. This law, therefore, could not be taken as our infallible guide in the study of the electrical fields of force in material insulators. The question arose then: Is there any other law to which we can appeal for guidance? Faraday's study of the electrical action of insulators, a subject to which Benjamin Franklin first drew attention, showed a way leading to the answer of this question. This study suggested one of the two great foundation pillars of the modern electromagnetic theory, which I venture to describe here briefly.

Faraday's method of representing graphically the field of force of electrical charges is well known, and it finds its simplest illustration in the well known conical tubes of force drawn from a point charge as vertex and expanding into all space. We are also familiar with Faraday's tubes[3] of force for any distribution of electrical charges. Faraday's pictorial method of describing the field of force leads to the same numerical results as Coulomb's law when the surrounding medium is free space without any material bodies in it. When, however, the surrounding medium contains material insulators then Coulomb's law offers small assistance in our study when these insulators have a variable specific inductive capacity and deviate otherwise from the characteristics of an ideal dielectric. It will be pointed out below that there are electric and magnetic fields which are not due to charges and in which Coulomb's law is altogether inapplicable. Faraday's picture of the field in terms of the tubes of force suggested to Maxwell a new law of force which is broader than Coulomb's law both in its meaning and its applicability.

Faraday's ideas concerning the physical character of the tubes of force were a guide to Maxwell, whose earliest studies of electrical phenomena, while still an undergraduate at the University of Cambridge, related to Faraday's *Physical Lines of Force*. In these early studies Maxwell made wonderful attempts to show by imaginative description and ingenious mechanical models what he saw in Faraday's tubes. But all these things were only a temporary scaffolding around a new structure which Maxwell was building. When the structure was finished the scaffolding disappeared and what do we see today? I shall try to answer this question.

In Maxwell's mind, just as in the mind of Faraday, the tubes of force were not mere geometrical pictures but represented physical entities capable of actions and reactions. Each volume element of a

3. The term "tubes" is preferable here to "lines" because it brings out clearly the three dimensional character of these structures.

tube of electric force is according to Faraday and Maxwell the seat of an electrical reaction against the change of its density; that is the number of tubes per unit area. When the surrounding medium is a vacuum or an ideal insulator, that is, a dielectric with a constant specific inductive capacity, then the numerical value of this reaction can be calculated. According to Maxwell's hypothesis, the electrical reaction in this case per unit length and unit cross-section of the tube is equal to the density of the tubes in the direction in which the reaction is considered, divided by the specific inductive capacity. The hypothetical reaction had a most significant corollary; it located the energy of the field in the volume elements of the tubes of force and assigned to each element, per unit of volume, an amount proportional to the square of the density of the tubes of force at that volume element. Dynamically, therefore, there is a perfect resemblance between the field of electrical reactions in ideal insulators and the field of elastic reactions in the interior of an elastically strained body which obeys the so-called Hooke's law.

According to this view, the charges transmit their action through the volume elements of the tubes against the reaction of the tubes. *When the field of electrical force is in equilibrium then the external actions coming from the electrical charges and the internal electrical reactions of the tubes are equal and opposite to each other at every point of space.* This form of statement is suggested by Newtonian dynamics and furnishes a law which conforms to Newton's third axiom. It is different from Coulomb's law in form and meaning, and it holds good no matter how the impressed forces are generated or what the physical character of the material bodies is upon which these forces are impressed. It is obtained from the hypothesis that the tubes of force are physical entities which react against a change of their density. There is nothing in Coulomb's law which suggests this hypothesis and there cannot be, because this law suggests nothing concerning the velocity or the mechanism of transmission of force between electrical charges, whereas a reacting tube of force was suggested to Faraday and to Maxwell by the intuition that electrical actions are transmitted through the tubes of force with a finite, and definite velocity which depends upon the dynamical properties, that is the reactions, of the tubes. The tubes of force attached to electrical charges or otherwise generated are, according to this hypothesis, the transmitting mechanism reacting in every one of its elements by reactions which in the case of the vacuum and of ideal dielectrics are identical in form with the elastic reactions of an ideal elastic body. This view of the field of electrical force is one of the foundation pillars of the Faraday-Maxwell electromagnetic theory. I shall next describe briefly the second foundation pillar of this theory.

What has been said above about our knowledge of electrical phenomena is also true of our knowledge of magnetic phenomena. It started its career as a science when Coulomb's measurements succeeded in formulating a law of force between magnetic charges. Since this law is identical in form with that for electrical charges, and since the presence of material bodies affects similarly a magnetic field as the presence of material insulators affects an electrical field it is obvious that the Faraday-Maxwell intuitive philosophy leads here to the same results as in the case of electrical fields of force. Coulomb's law can, therefore, be replaced by a law which is identical in form with the law formulated above for electrical fields. It is as follows: *When the field of magnetic force is in equilibrium then the external magnetic actions and the internal reactions of the magnetic tubes of force are equal and opposite to each other at every point of space.* Description and hypothesis serve here the same object as in the case of the electric fields, namely, to point out that the magnetic tubes of force are the transmitting mechanism of the magnetic force and that the quantitative relation between the forces impressed upon the tubes and their reactions is one of the determining factors of the mode of propagation.

It is obvious that so far I have been endeavoring to show that Faraday's and Maxwell's views paved the way to the formulation of new concepts, the concepts of electrical and magnetic actions and reactions, which like ordinary material actions and reactions obey Newton's third law. These endeavors will be continued in what follows.

The law of equality between electrical and magnetic actions and their respective reactions in fields which are in static equilibrium can, obviously, tell nothing definite about the velocity of propagation. Reactions brought into play when this equilibrium is disturbed must be considered. Do they exist, and if so, do they show that the velocity of propagation of electrical force is the same as or different from that of the magnetic force? The electrical science prior to Oersted's and Faraday's discoveries could not have answered this question. These discoveries supplied the necessary knowledge. Broadly stated they revealed the following new truth: Oersted discovered that electrical charges moving through conductors produce magnetic tubes of force which are interlinked with the conductors; Faraday discovered that magnetic charges and their tubes of force produce by their motion or variation electrical forces in conducting circuits which are interlinked with these tubes. This description of the discoveries intentionally emphasizes the two facts, namely, that Oersted made his discovery while experimenting with conduction currents, and that Faraday explored the electrical field in conducting wires, only, which are interlinked with the magnetic tubes of force. The laws resulting from these experiments, namely, Ampére's law and Faraday's law, were necessarily limited to the conditions of the experiments which led to their formulation. Neither one nor the other were sufficiently

general to give direct information concerning the unknown reactions associated with the variable electric and magnetic tubes of force at any point of a dielectric. Oersted's and Faraday's experiments did not detect them, nor was it obvious how to detect them experimentally. New hypotheses were needed and Maxwell was the first to formulate them; they were as follows: First, a variation of the flux, that is the total number of electrical tubes of force through any area is equivalent to the motion of electrical charges through that area; in other words, the so-called displacement current produces according to Maxwell the same magnetic effect as the conduction or convection current. Secondly, the variation of the flux of the tubes of magnetic force through any area produces an electromotive force around the boundary curve of this area which is independent of the material through which this boundary curve passes. These two hypotheses extended the meaning of the Ampére and of the Faraday law and gave them that symmetry which is expressed in the following statements:

The rate of variation of the electric flux through any area is equal to the magnetomotive force in the circuit which forms the boundary curve of that area.

The rate of variation of the magnetic flux through any area is equal to the electromotive force in the circuit which forms the boundary curve of that area.

The first statement represents Maxwell's generalization of Ampère's law, and the second that of Faraday's law. Mathematical physicists call them Maxwell's field equations. This name does not convey clearly their physical meaning, nor does it express fully their historical significance. Prior to the time of Oersted and Faraday there were only a few, rather feeble, processes of generating and impressing upon material bodies electric and magnetic forces; frictional machines, galvanic cells, action of permanent magnetc, etc. . . Ampère's and Faraday's generalized laws describe new processes of generating and impressing magnetic and electric forces upon any part of space. They might be called Maxwell's laws of electrodynamic generation, or briefly *Maxwell's laws*, the rest of the proposed title being understood. These laws give the total sum of the electric and magnetic forces impressed by those processes upon any circuit; the energy principle tells us that this sum is equal to the sum of the electric and the respective magnetic reactions in the circuit. The parcelling out of the total impressed forces thus generated among the volume elements of the circuit and the character of the reactions of each volume element must be determined by the character of each problem and by the physical properties of each volume element of the circuit. Circuits in ideal isotropic dielectrics present the simplest illustration of the general procedure, and this was the subject which Maxwell considered first. In this case the reaction per unit cross-section and unit length of the circuit is, as already pointed out, equal to the ratio of the flux density to the specific inductive capacity, or permeability, respectively, and this reaction must be equal to the force generated by the variable fluxes and impressed per unit length of the circuit. This leads to a reciprocal relation between the electric and magnetic reactions in variable fields which in an isotropic dielectric exhibits a process of propagation identical in form with that obtained by Newtonian dynamics for the actions and reactions in an isotropic, incompressible, elastic medium. Maxwell's greatest achievement is, in my opinion, his introduction into the electrical science of new concepts, electric and magnetic actions and reactions, which are subject to the same laws as the corresponding concepts in Newtonian dynamics. But it should be observed here that Maxwell's success was due to Faraday's suggestive description of the electric and magnetic fields in terms of tubes of force and to the intuition which created the epoch-making hypotheses endowing these tubes with dynamical attributes formerly belonging to material substances only. These hypotheses demanded experimental verification; Hertz seized the opportunity and furnished the epoch-making demonstration of the correctness of Maxwell's views.

The propagation of force through an ideal elastic solid makes the velocity of propagation depend upon two constants only, the density and the elastic constant. The first determines the inertia reaction and the second the elastic reaction per unit volume of the solid. Similarly in the propagation of the electric force through the electric and magnetic tubes of force in an ideal dielectric the velocity of propagation depends upon two constants only; the specific inductive capacity of the tubes and their magnetic permeability. One determines the reaction of the electrical tubes of force, and the other the reaction of the magnetic tubes. These reaction constants determine the velocity of propagation through the electric and magnetic tubes in the same manner as density and elastic constants determine the velocity of propagation through ideal elastic bodies. The question arises, which of the two reaction constants of Faraday's tubes corresponds to the density and which to the elastic constant of material bodies? In other words, which of the two constants is characteristic of the inertia constant of the tubes?

The generalized laws of Ampère and of Faraday, which I call the Maxwell laws, suggest a permissible answer to this question. They indicate a scheme which demands one primary or fundamental flux only; the electric flux. A variation or velocity of motion of the electric flux generates, according to the first Maxwell law, magnetic forces and corresponding magnetic fluxes which in an isotropic dielectric are proportional to the impressed magnetic forces; the factor of proportionality being the magnetic permeability of the tubes of the magnetic field. If, therefore, we consider the magnetic flux of the field, thus generated, as the momentum of the varying or moving electric flux, since it is proportional to its rate of variation or velocity of motion, then

the electrical field generated, according to the second Maxwell law, by the variation of the magnetic flux will be due to the change of this momentum. According to this scheme the permeability constant in the electromagnetic theory would correspond to density in the theory of propagation through elastic solids.

Electron physics supports this scheme. It traces the origin of all magnetic forces of magnets to the orbital motions of electrons. This reminds us of the old Ampèrean conception. Magnetic tubes of force associated with so-called permanent magnets are, according to electron physics, the result of the motion of electric tubes of force attached to electrons. Maxwell always associated with magnetic tubes of force the momentum of some electric motions; what Faraday called the electrotonic state, he called the electro-kinetic momentum of a circuit, that is the magnetic flux interlinked with the circuit. The reactions of varying magnetic tubes of force are, therefore, inertia reactions and their reaction constant, the permeability, should, as already pointed out, be considered as corresponding to the density of elastic solids, whereas the reciprocal of their specific inductive capacity corresponds to the elastic constant. Faraday's tubes of force in free space have, in electromagnetic units, a permeability equal to unity and, measured in the same system of units, an exceedingly small specific inductive capacity. They behave, therefore, like incompressible elastic bodies of moderate density but of very high elastic constant for shearing strains. It is equal to 9×10^{20}. Hence the great velocity of propagation of electromagnetic disturbances through tubes of force in free space, as experimentally verified by Hertz.

Electrical propagation through ideal dielectrics, including the vacuum, demands, according to the above picture, nothing more than Faraday tubes of electric force (which I call here *primary flux*) capable of two distinct reactions, one an electrical reaction and the other a magnetic, that is an inertia, reaction. The tubes react like a material medium of reasonable density but of most extraordinary stiffness. But neither this similarity to material bodies nor anything else in our present knowledge of electrical phenomena justifies the hypothesis that they consist of a substance which has qualities of ordinary matter in bulk. One cannot resist the temptation of asking the question: What are these tubes made of? I venture, therefore, to offer the following pardonable suggestion.

Our ideas of these tubes are associated with our concepts of electrical charges which are the terminals of the tubes when they have a terminal. In this we follow in the footsteps of Faraday. It is not an unreasonable hypothesis to assume that they are made of the same fundamental substance of which the electrical charges are made. The name "electricity" may, therefore, be reserved for that substance, whatever it may be, so that we may say: The medium which transmits electrical disturbances is "electricity," meaning thereby the electrical tubes of force. Light is an electrical disturbance and it is, according to this view, transmitted by electricity. The concept suggested by the word "electricity" is much more definite than that suggested by the words "lumeniferous ether," because we associate with electricity two perfectly well known and experimentally determinable reaction constants, that is the reaction constants of the primary flux of force at rest and in motion. These are the only attributes that we can dynamically predicate of a material substance hence the concept "electricity" is dynamically just as definite as the concept "material substance"; the concept "ether" is not.

Perhaps I have dwelt too much upon that part of the electromagnetic theory which is a little outside of the daily problems of the electrical engineer. Some people think that it is entirely outside of the theory which underlies electrical engineering problems. Permit me to show you, as briefly as I can, that this is not so, and that the same form of laws and the same dynamical methods apply to electrical engineering problems as to the problems discussed above. Electrical engineering problems deal with actions and reactions in electrical and magnetic circuits and so does the general electromagnetic theory. I have pointed out how starting with Coulomb's law a more general law was formulated for the field of force due to electrical or to magnetic charges at rest, the law of equality of actions and reaction in every volume element of the field in static equilibrium. The validity of this law was maintained for the dynamical equilibrium of variable fields when Ampère's and Faraday's laws were formulated by Maxwell in their most general form. The principle of conservation of energy demands that this law be always true irrespective of the physical character of the circuit or of the process of generating the impressed forces. This furnishes then the most fundamental basis in theoretical electrical engineering. It may be stated as follows:

In every circuit or part of a circuit the algebraic sum of electrical reactions is equal to the algebraic sum of the impressed electrical actions.

Omit the words "electrical" from this statement and you have the most fundamental law in Newton's dynamics, showing that "electricity" obeys the same fundamental law which ponderable matter obeys.

Take for an illustration an electrical circuit in which we have a constant electromotive force, generated by a voltaic cell, and a constant current flowing through a conducting wire. Consider any two points on the wire. Heat is generated in the wire between these two points and, therefore, there must be an electrical reaction in the wire between these two points. Heat is the result of the work done against this reaction by the impressed electrical force transmitted by the battery. This reaction may be called a *resistance reaction*, whereas the impressed action is the difference in potential between these two points. The law of equality of action and reaction says: The resistance reaction is

equal to the difference of potential. This relation is independent of the so-called "Ohm's Law." When, however, the wire is maintained at constant temperature then its resistance reaction is found by experiment to be proportional to the current; this empirically established characteristic of most metal wires is called Ohm's law. It really is not a law any more than Joule's rule for the rate of heat generation by a current flowing through a metal wire. Both are accurate empirical descriptions of a physical characteristic of most metal wires. It is occasionally stated with some show of disappointment that the flow of current through a gas does not obey Ohm's law, which really means that the resistance reaction is not proportional to the current, and that it cannot be described as simply as the resistance reaction of a metal wire. That a conducting gas should react differently than a conducting metal wire should not surprise anybody; but it seems that it does.

Consider, as another simple illustration, a toroidal magnetic circuit consisting of several different radial sections of different kinds of steel separated from each other by small air gaps and magnetized by a current flowing through turns of wire wound uniformly around the toroid. The total magnetomotive force generated by the current is given by Ampère's law. Each part of the magnetic circuit receives its definite share of the total magnetomotive force; this share is the magnetizing force impressed upon that part of the circuit. In each part of magnetic circuit the impressed magnetizing force is equal to the magnetic reaction of that part, so that according to the fundamental law the sum of the magnetic reactions is equal to the total impressed magnetic actions, which is the magnetomotive force. This is the fundamental law, whereas the usual method of calculating, roughly, the magnetic flux from impressed magnetizing forces and reluctances by making use of a new kind of Ohm's law for the magnetic circuit is, in my opinion, a misleading use of the word law. This spurious Ohm's law is abandoned, of course, as soon as we attempt to devise an experimental method for measuring hysteresis losses during a complete cycle of magnetization, but we do not abandon the dynamical law that in every part of the magnetic circuit the magnetizing force is equal to the magnetic reaction. On the contrary, we could not without it interpret dynamically the hysteresis losses during cyclic magnetizations.

When in a network of linear conductors alternating current generators are located at various points of the network, the current distribution in the network can be calculated by setting up equations for each circuit, which state the fundamental dynamical law that in each circuit the algebraic sum of electrical reactions is equal to the algebraic sum of impressed electromotive forces, generated by the alternators. To call these equations mathematical expressions of a Kirchhoff law, as some do, is unpardonable abuse of language. Kirchhoff gave the *rule* that for any circuit in a network of metalic wire conductors in which there are sources of constant electromotive force the algebraic sum of the electromotive forces is equal to the algebraic sum of the products of current and Ohmic resistance; but he never suspected that this is a special case of the fundamental dynamical law given above.

It is true that in 1858 Kirchhoff, in his analysis of electrical propagation along an overhead telegraph wire, stated correctly the relation between the electrical reactions at any element of the wire, and in this statement he was guided by Thomson's discussion of electrical propagation over a submarine cable. But neither Thomson nor Kirchhoff were aware of the general law, stated above. Maxwell's Electromagnetic Theory had not yet been published, and prior to that publication the general law implicitly contained in this theory, and which is today the foundation of electrical engineering, could not be formulated.

The several simple examples, cited above, suffice to illustrate clearly that electrical engineering problems are formulated in the same way as the problems in the general electromagnetic theory. Their solutions are obtained by the application of the same form of the fundamental laws employing the same methods of reasoning and the same terminology which Newton had formulated when he created the science of dynamics. The possibility of describing electrical phenomena in terms of Newton's concepts and language is one of the greatest achievements of Faraday and Maxwell. Law, description, and hypothesis were never employed with greater effect than by the genius of these great prophets of the electrical science.

THE POWER OF NATURAL LIGHTNING

The electric energy now produced at Niagara Falls is less than that provided by nature in the thunder storms always in progress throughout the world, is the assertion of F. W. Peek, Jr., consulting engineer of the Pittsfield Works of the General Electric Company, in an address at a joint meeting of the Detroit and Ann Arbor Sections of the American Institute of Electrical Engineers on Tuesday night, May 26, Ann Arbor, Michigan. The talk, "Lightning and Other High-Voltage Phenomena," described the interesting work of investigation which is being carried on with artificial lightning generators in the Pittsfield laboratory.

Statistics show, said Mr. Peek, that at any instant there is an average of 1800 thunder storms in progress throughout the world, giving 300,000 lightning flashes per hour. Investigations with laboratory lightning disclose the fact that the energy of a severe lightning flash is about four kw-hr., the total energy represented by 300,000 severe flashes therefore being, 1,200,000 kw-hr., or more than 1,500,000 horse-power, operating continuously to supply the world with severe lightning.

The Electrical Engineer in the Merchant Marine

BY G. A. PIERCE[1]
Associate, A. I. E. E.

Synopsis.—There is no problem relating to marine electrification which is of more importance than that of the engineering and operating personnel.

At the present time no adequate provision is made by law to give assurance that the operator of an electrical plant on shipboard is fully qualified. Private or individual supervision of the necessary qualifications is not adequate; a definite legal status is essential.

Efforts which are going forward at present to secure proper supervision over the qualifications of electrical operators, and of the maintenance of the electrical plant are deserving of all possible support.

THERE is no problem relating to marine electrification which is of greater importance than that of the engineering and operating personnel. It is of comparatively recent origin, and has even more recently become a question of first importance due to the rapid increase in marine electrical applications during the past ten years. The first electrical installation of dynamos and lighting on shipboard was in 1879, and the first power installation of note was in 1894. Rules for the installation of lighting were not issued until 1891, and for power, only four years ago.

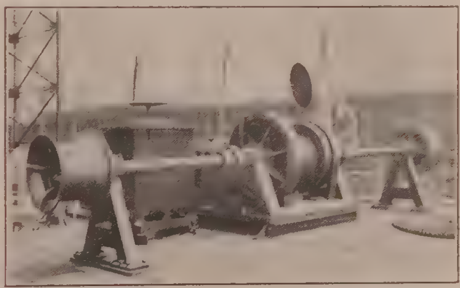
The Diesel engine, now accepted as one of the most efficient and reliable means of ship-propulsion, has given great impetus to marine electrical development. This is because the pumps, ventilating sets, winches and other auxiliaries which are ordinarily operated by small steam engines on a steam propelled ship, must be operated by electric motors on a Diesel-driven ship. Experience has shown electrically driven auxiliaries to be so efficient and satisfactory that their use is constantly and rapidly increasing, even where steam or steam-electric propulsion is employed.

It is important to note, therefore, that electrical installations on shipboard are no longer in the nature of auxiliary equipment of minor importance; they are concerned with the vital functions of the ship, and must receive just as careful attention and intelligent supervision as the main engines, which can not run five minutes if their auxiliaries are shut down or out of order.

The present age of electricity on shipboard is analogous with the age when steam engines replaced sails as motive power. In 1852, when it was found expedient to replace sailing vessels with steam vessels, legal requirements were established for knowledge of steam engines for marine use and licenses were granted on this basis. The readjustments of personnel and methods which are needed to-day are similar in nature to those which were brought about in the earlier evolution. We are fortunate, however, in having much better guidance and example than was available at the earlier date; the Navy, in contrast to the Shipping Board, has, to a large extent, solved the personnel problem as it applies to them, and the work to be done in the merchant marine is largely the extension and application of the principles the Navy has evolved.

The definition of the word engineers, we find is "*one who is skilled in the principles or practise of any branch of engineering; one who has charge of and manages an engine*" and an engine is "*an apparatus for producing some mechanical effect.*"

From this definition, the electrical engineer on shipboard does not today exist in the eyes of the law,



ELECTRICAL MACHINERY FOR HANDLING CARGOES

although his wares are revolutionizing the loading, carrying and discharging of cargoes and the propelling of passenger and naval vessels.

The reason that he does not exist is very apparent: steam and motor (internal combustion) engineers are required by years of training and examination to satisfy the Steamboat Inspection Service of the Dept. of Commerce that they are skilled in the art of steam or combustion engines, and they are rated and licensed according to their training and knowledge.

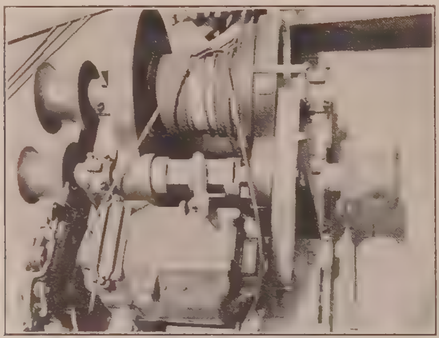
1. Wm. Cramp & Sons Ship & Engine Bldg. Co., Philadelphia, Pa.

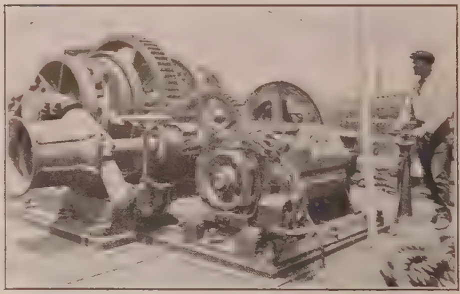
Presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

It is surprising to note, therefore, that only the most elementary and meager electrical experience and knowledge is legally required of these men, irrespective of the amount of electrical apparatus they are required to supervise and maintain.

There are many cases on record where the knowledge of the licensed ship's engineer has been inadequate and damage or danger has resulted. The following specific examples are given to show how serious are the troubles which may result from incompetent supervision:

In one case the repeated blowing of a fuse on the switchboard was corrected by installing a piece of No. 8 copper wire in place of the fuse, with the result that the circuit was burned open behind some panel work. In another case, one of the engineers observed that the temperature of the cooling water on a motor-driven pump was high; he had somehow come by the knowledge that, by shifting the brushes on a motor, the speed could be increased, and this he proceeded to do to increase the flow of water rather than look for the trouble elsewhere. The result was that all the conductors were thrown out of the armature. A spare armature was installed, and ruined in the same way.





Deck Winches, Electrically Operated

Case C1. Passenger Ship Operation: Ex-German ship. Emergency lighting system required by Federal Law. In making certain changes in passenger accommodations third class, it was found by the electrical inspector that this emergency lighting could not be operated from storage battery supply, and that many of the connections were not operative, so that, in a disaster at sea involving the dynamo plant, the ship would be in darkness. Neither the engineering force of the ship, including the electrician (wireman), could make recommendation for rectifying defects.

Case C2. American-Built Passenger Ship. The engineer's repair list required a section of new bus bar on the main switchboard to replace a section which had been badly overheated. No recommendations were made to overcome the cause of overheating, which was not local to the board but in the generators, due to a link connection being removed from field circuit. The same trouble would have recurred under like conditions, causing a complete shut-down of dynamo plant for upwards of about two minutes. Neither the chief engineer nor his wireman made, or were capable of making, the proper recommendations.

Case C3. American-Built Passenger Ship. Arrive in port with emergency-lighting storage batteries inoperative, due to neglect by personnel and too high charging rates; not reported by engineering force. Detected through examination and test, but would have proceeded to sea with this safety equipment inoperative had it been left to the engineering force and wireman.

Case O1. A freight ship with a limited number of passenger quarters: Was troubled with lamps burning out, and varying loads on the generator, causing a great fluctuation in the lights. The case was investigated and located in the governors of the engines. This being brought to the attention of the engineer, he expressed surprise that the speed had anything to do with the voltage as he thought if the voltage was once adjusted to the proper value it would always remain there.

Electric Winches in Operation

Case O2. A passenger and freight ship: Required two generating sets in operation on the peak load; the chief engineer reported one set defective and not in operating condition due to excessive heating. Upon investigation it was found that one set was almost under a vent-pipe and thus received a large amount of outside air. The other was some distance away in a corner without any ventilation, and it was this latter set which was reported defective. Tests were run on each set and the rise in temperature on both sets was well within the same limit. The Chief Engineer did not consider the surrounding air as a factor in the case, and because one machine would run cool, he was sure the other machine was defective and dangerous to operate,

as it was so much hotter. He had been operating one generator on a very big overload or switching off considerable of the lighting load to keep the machine from getting too hot.

Case O3. A Small Diesel Ship: Left the yard of the builders in first class condition; the engineering force on board knew nothing concerning electrical equipment and before the ship left the port on her first trip out, it required three electricians from the shipyard to repair the damages done by the engineers. After four months, the entire engine room force was discharged and a new force employed, great care being exercised by the operating company to get one engineer who was thoroughly competent to care for the electrical apparatus.

Consideration of these and many other examples which might be given may well excite curiosity as to the system which permits men so inadequately trained to be put in charge of equipment upon which property and life depends. It is instructive to analyze the official requirements of a Chief Engineer and the examinations by which his capability is judged. The following is an extract from the rules of the Steamboat Inspection Service:

Main Engine, Motorship California

"Classification of Engineers

Chief Engineer of Ocean Steam Vessels.

40. An applicant for license as chief engineer of ocean steam vessels shall be eligible for examination after he has furnished satisfactory documentary evidence to the local inspectors that he has had the following experience:

First: One year's service as first assistant engineer of ocean or coastwise steam vessels; or,

Second: Two years' service as chief engineer of Great Lakes and all other lake, bay, or sound steam vessels of 2500 gross tons or over; or,

Third: Three years' service as first assistant engineer of lake, bay, or sound steam vessels of 2500 gross tons or over; or,

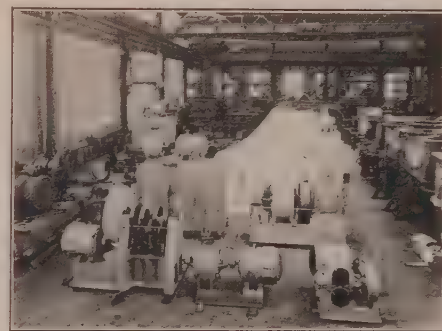
Fourth: Two years' service as second assistant engineer of ocean or coastwise steam vessels, or two years' combined service as first and second assistant engineer of ocean or coastwise steam vessels; or,

Fifth: One year's service as assistant engineer on ocean or coastwise steam vessels for license as chief engineer of steam vessels of 750 gross tons or under."

Without quoting additional detail, it becomes evident that, in order to become a first assistant, he must serve one year as second assistant and pass an examination.

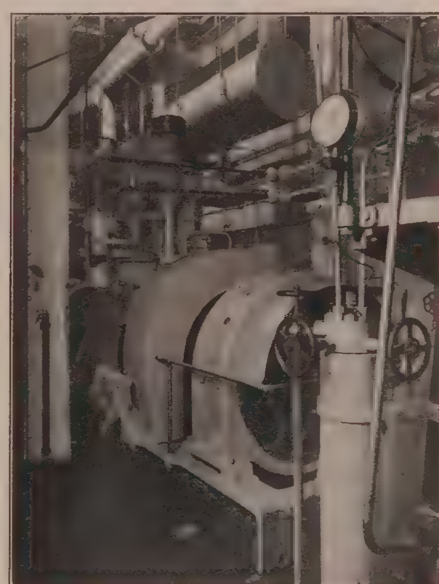
To become a second assistant, he must serve one year as third assistant and pass an examination.

To become a third assistant, he must serve three years as fireman or two years as oiler or two years as machinist and one year at sea.



Engine Room Auxiliaries, Motorship California

Therefore, a chief engineer cannot get his papers in less than four years. The extent of his required electrical knowledge may be illustrated by the following questions which are taken from a typical examination paper.



Auxiliary Engine Driving Generators, Motorship William Penn

Electricity (Chief, Ocean, S. F.)

A. How many processes do you know to produce electricity?

B. Name the essential parts of a dynamo on direct and alternating current machines.

C. Describe the causes of the following dynamo troubles:

D. Sparking of commutator; heating of commutatator or brushes; heating of armature; heating of field magneto; heating of bearings; speed too slow; failure to generate.

E. What are the most common methods of wiring?

F. How do you regulate load on a dynamo?

G. What is a dynamo?

ENGINE ROOM AUXILIARIES

H. How many different kinds of electric currents are there in use? Describe them.

I. Describe how a modern ship is wired so as to comply with the rules of this service.

While the scope and nature of these questions is in mind, it may be of interest to see some of the electrical equipment which this man has under his charge. Assuming that we have to do with a motor ship, Fig. 1 shows the main engines, which depend for their operation upon the electrically driven auxiliaries which follow. This engine, installed on the *William Penn* is the most efficient marine prime mover ever devised.

TRIAL TRIP MOTORSHIP WILLIAM PENN

The *William Penn* left the builder's works in June, 1921; has made five complete voyages around the world and started on the sixth voyage, September 18th, 1924. The vessel has traveled over 175,000 miles, averaging between 10.5 and 11 knots, with a fuel consumption of 0.308 lb. of oil per indicated horse power.

The *Californian* and *Missourian*, equipped with the same size and design engines, left the builder's works May, 1922; have traveled over 200,000 miles, averaging between 11.5 and 12 knots and show the same fuel consumption as the *William Penn*.

The ship is shown on her trial trip.

The principal auxiliaries are as follow:

Steering gear, windlass, capstan, deck winches, engine room bilge, sanitary, fresh water, salt water, lubricating, cooling pump and compressor all motor driven.

These different pieces of equipment require expert knowledge for their proper care and operation. Ship builders and ship owners appreciate this, and they have been greatly assisted by some of the large electric manu-

SWITCHBOARD, MOTORSHIP WILLIAM PENN

facturers who have organized regular courses of instruction. These were first undertaken during the war, when there was a great scarcity of trained men. In contrast to the ideas of the Steamboat Inspection Service as regards the knowledge required for marine electrical service, the courses of instruction arranged by these companies are very thorough and complete. Arrangements were made with the Government, through the Navy and the Shipping Board, to send large numbers of engineers to their shops. At one

STEERING GEAR, MOTORSHIP CALIFORNIA

plant, 1300 men received these courses of training, approximately 500 of which were naval officers. The seriousness of the question of training in the minds of the manufacturers is best evidenced by the following outline of subjects covered by lectures and ship instruction.

Turbines and their Application to Marine Practice.
Inspection of a 2500-h. p. Marine Geared Turbine.
Design and Construction of Marine Geared Turbine.
Clearances and adjustments.
Disassembly of valves.
Steam and vacuum conditions.
Care and Operation.

Elements in Economy of Operation of Marine Installation.
Marine Auxiliaries.
Lubricating Systems.
Theory of Condensers.
Chemistry of Oils.
Motor Applications to Auxiliaries.

We are now passing through a period of training engineers for combustion engines and as the combustion engine is associated with electrical auxiliaries, it brings the electrical engineer on shipboard into prominence as a definite problem.

Naturally, we train steam engineers in the refinements of proper proportions of air and oil to get the complete combustion which is necessary for the successful operation of a combustion engine, also regarding the temperature of lubricating oil and circulating water and other details which make for the most economical operation.

It will be readily appreciated that there is as much difference between marine engineers as there is between mechanics of any trade. Some are reliable, accurate, painstaking and always endeavoring to make the best possible record, while others are quite the reverse. All of these men have had to serve the same period at sea and pass an electrical examination such as is quoted earlier in this paper. Electrical apparatus placed under the care of men who have not had to demonstrate, by experience and examination, that they are qualified to care for same, is operating under a heavy disadvantage.

The ship owners, having had long experience with bills for maintenance, have been quick to appreciate the need for trained men and have done their best to coöperate with the ship builders and the manufacturing companies. They are handicapped by the lack of a definite standard such as is available in the license requirements of steam and internal combustion marine engineers. This condition may be partly explained by the fact that the examination of engineers for licenses is left by law to the local Inspectors of the Steamboat Inspection Service and these Inspectors are generally Chief Engineers who entered the Steamboat Inspection Service before electricity was used to the extent it is to-day.

But this is not all of the problem; the electrician has no standing, has no fixed pay and it is difficult to obtain suitable men and to determine a proper wage. Further, the architect in designing ships overlooks the electrician entirely, he being a newcomer and he is usually assigned to an oiler's room. Concession and special rulings have to be employed to correct this as men who are not licensed have no uniforms. These have been provided in certain cases and special ruling made to have them eat in the engineers' mess with the uniformed licensed men.

You can readily appreciate that the electrical engineer on shipboard is a good deal handicapped, which fact no doubt dampens his ardor for his new position.

The general situation is not improved by the fact that it is often necessary to pay a good electrician more than some of the licensed men, a condition which is not always comprehensible to them. This feeling, in one case, did not exclude the chief, who threatened that when he got to sea, he would assign the electrician to the most menial job one could imagine. Fortunately the electrician in this case was also a diplomat and in a very short time was almost inseparable from the Chief and that Chief is now in a fair way to become an electrician. The following illustration, which is interesting, as in the nature of a puzzle.

Find the Electrical Engineer

The above illustration shows the respective relation of the electrical engineer to the other engineers.

The salaries paid to the various engineers are intimated above and it is also indicated that the electrical engineer's location should be elsewhere. This condition is not peculiar to motorships alone, as on some large passenger ships, having a plant load requiring four 100-kw. sets, the electrician is paid more than some of the engineers and on other ships of 15,000 tons, the electrician is paid as low as $75.00 per month, less than two-thirds of the lowest paid engineer and only slightly more than an electrical helper on shore, working 44 hours per week.

The duties of an electrical man on a motorship are such that he has replaced what would be the deck engineer on a steamship, having in his care the maintenance and operation of the electrical and mechanical features of all deck machinery, steering gear, winches, capstan and windlass and ice machine, the supervision of all engine room motors, generators and switchboard. The universal success attending all of these ships in operation would indicate that the attitude of the builder and owners has been well taken with regards to the selection of men. However, they should be assisted by the authorities by laying down some rules for the training and licensing of competent marine electrical engineers. This is particularly true when it is considered that the electrical installation amounts to 20 per cent of the value of the total machinery on the vessel and is absolutely indispensable.

Definite legal establishment of the necessary requirements for electrical knowledge in the merchant service will lead to direct and indirect benefits to ship builders,

ship owners and ship operators. At the present time there are no fully organized courses available in colleges and schools and so long as there is no definite demand for them, it is unlikely that any will be organized. Until educational institutions take over the work of training our marine electrical engineers, the expense will probably be borne, as at present, by the manufacturers, with resulting increased cost of electrical equipment.

The question naturally arises, how is the problem handled on ships under other flags.

In the Scandinavian countries, the conditions are pretty much the same as in our country. The larger vessels carry electricians and are rated in pay about as the second engineer.

On the British ships, electricians are not licensed as such, but frequently licensed men are electricians, as on some motor-ships and large steamships with an extensive electrical plant, the electrician ranks, in pay, almost equal to the first assistant engineer and in the latest motor ships, carry a chief, and first and second assistant electrician.

The examination and licensing of marine engineers, steam, motor and electrical, is supervised by the British Board of Trade. This organization very efficiently superintends the requirements and licensing, and the men who receive their papers under its approval are thoroughly qualified.

In concluding, the need for thorough and frequent inspection of the entire electrical installation cannot be too strongly emphasized.

The Committee on Marine Applications, A. I. E. E., under whose auspices this paper is presented, is formulating details of a program aimed to improve the conditions which have just been outlined. At the present time, definite recommendations are not ready but it is hoped that they may be presented to the Institute shortly and that the foregoing introduction will serve to justify the hearty support which the Committee will ask and recommend.

Voltage Control Obtained by Varying Transformer Ratio

L. F. BLUME[1]
Associate, A. I. E. E.

Synopsis.—*The general principle of changing the ratio of power transformers without interrupting the load, by means of transformer taps and a multiple circuit, is described. Although this principle is not new, a detailed description of the characteristics of this method of securing voltage control is desirable on account of the increasing number of applications to large power transformers.*

General Need of Voltage Control

The steady and rapid growth of electric systems throughout the country, both from the standpoint of the amount of kv-a. handled and the area covered, is making increased flexibility in voltage control more imperative. The characteristics of this growth which have directly affected the problem of voltage control are:

a. Connecting two or more generating plants on one system;

b. The gradual increase in reactance of the system, either on account of the greater length of line, or, where large concentration of kv-a. is involved, on account of the reactance deliberately added to limit the value of short-circuit current;

c. The bringing together into one system greater diversity, and increased number of loads.

These conditions all tend to make the problem of voltage control more complicated. Without adequate regulating devices, it would become impossible to maintain proper division of current in these systems and to hold even approximately constant the voltage at the various parts.

The existence of these facts has resulted in an increasing interest in the various methods of voltage control and has created a demand for regulating equipment capable of maintaining a proper division of large amounts of kv-a., independent of station-bus voltages.

It is hardly necessary to develop an argument for the existance of taps within transformers, for, notwithstanding the reluctance of the average transformer designer to furnish taps, there has existed a steady demand for them so that their use in power transformers is almost universal. This situation is rather remarkable in view of the limited use to which these taps can be put, owing to the fact that it is generally necessary to disconnect the transformer from service and remove the cover or open a manhole in order to change the ratio. This limitation made the tap useful only to adjust voltage to the most suitable value for average conditions of operation, but it could not be used to compensate for varying voltages from no load to full load. The development of the ratio ad-

1. Of the General Electric Co., Pittsfield, Mass.

Presented at the Regional Meeting of Dist. No. 1, Swampscott, Mass., May 7-9, 1925.

juster, with an operating handle brought out through the cover, only made the process of tap changing more convenient, and emphasized the limitations in their use.

It is, however, possible by employing two transformers operating in parallel on a given line to shift from tap to tap without dropping the load, if the operating handle is brought out of the tank and is located in such a place that it may be operated with the excitation still on the transformer. Fig. 1 represents two transformers connected in parallel on both high and low voltage sides; each transformer is provided with ratio adjusters with operating handles brought out to a convenient place. The taps can be controlled by first throwing circuit breaker *A*, which shifts the load from transformer *A* but does not remove the excitation, since the high voltage side is still connected to the line. The ratio adjuster in transformer *A* now can be moved to the next position after which circuit breaker *A* is

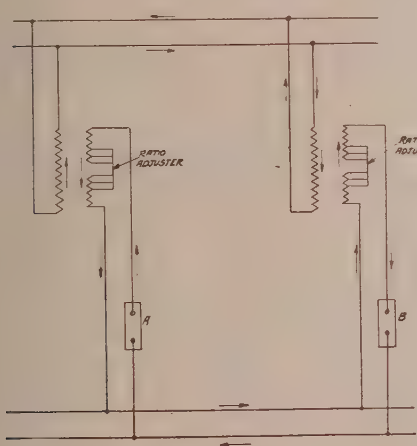


FIG. 1

again closed. The two transformers are now operating with unequal ratios in parallel and a circulating current, as indicated by the arrows, flows between them. Next, the circuit breaker *B* is opened so as to permit the ratio adjuster to shift in transformer *B*. Circuit breaker *B* is then closed and the two transformers are again operating under normal conditions.

Examining more closely what happens during this process, it is seen that during the interval when either of the breakers is open, one of the transformers is carrying double load, therefore the impedance drop across that transformer is doubled. It is also important to note that when one of the circuit breakers is open, the voltage which exists across the open breaker is not the line voltage but a very small fraction of it, owing to the fact that the disconnected transformer receives excitation from the high voltage side. Thus, the voltage which the breakers are obliged to open is equal to the difference in the ratio of transformation of the two transformers plus the impedance drop which exists in the loaded one.

Of course, this rather tedious method of operation is liable to result in serious mistakes; for example, if a ratio adjuster is shifted without opening the proper breaker, the rupturing of current by the ratio adjuster may possibly result in a short circuit within the trans-

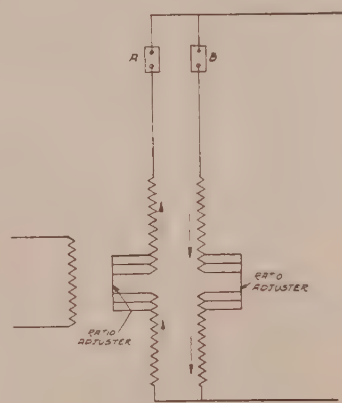


FIG. 2

former. Furthermore, the doubling of the load on one winding doubles the impedance drop, so that the poorer regulation during the switching period may result in an undersirable fluctuation in line voltage. Of course, these defects are avoided in properly designed ratio control equipments.

TRANSFORMER CIRCUITS

By designing the transformer with a multiple circuit and connecting according to Fig. 2, the various diffi-

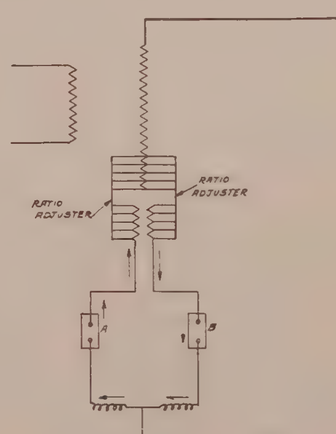


FIG. 3

culties cited above are readily overcome. The reactance between multiple paths can now be controlled independently of the main transformer reactance, and it can be made small enough to prevent objectionable fluctuation in voltage during the process of switching.

Furthermore, with both ratio adjusters in one tank, a suitable mechanical drive can be readily applied.

In some cases, practical consideration in the details of design make it desirable to depart somewhat from the simple arrangement illustrated in Fig. 2. For example, if the number of taps involved or the use of a parallel path increases the cost of the transformer, it may be advisable to place only a small portion of the circuit in multiple, as shown in Fig. 3. In this case, it may be necessary to add an auxiliary reactance to

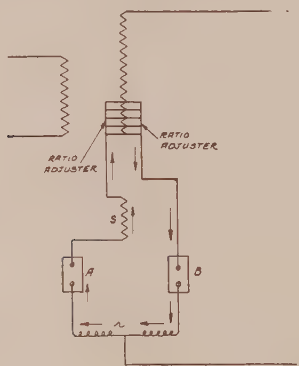


Fig. 4

limit the circulating current. A still further modification of the circuit is possible, in which the transformer circuit is not divided at all, but ratio adjusters and circuit breakers constitute the parallel circuit. An example of this circuit is shown in Fig. 4. By introducing an auxiliary coil *s* in one side of the multiple path, consisting of one-half of the turns between adjacent taps, the voltages obtained when one breaker is closed are staggered with respect to the voltages obtained when the other breaker is closed. By this means, twice the number of voltages are obtained as the number of taps provided.

Principle of Operation

All the various methods above described involve the same underlying principle. In its simplest diagrammatic form, this principle is illustrated by the connection diagram Fig. 5. To this figure, and equally well to all the preceding figures, the following general statement applies. The process of shifting to an adjacent voltage consists in transferring the load from circuit *A* to circuit *B* by closing the circuit at *B*, before opening the circuit at *A*. During the short interval which exists when both the *A* and *B* circuit are connected to the line, a circulating current flows in the circuit *A B*, limited by the impedance of this circuit. To prevent excessive current from flowing in the local circuit, care must be taken to insure that it contains a sufficient amount of impedance.

In the design of the amount of reactance which is to limit the circulating current when adjacent taps are connected, two conflicting requirements must be kept in mind, namely, first, that the circulating current must not be excessive, and second, that variation in reactance during switching cycle is not so large as to introduce undesirable fluctuations in line voltage. Reactance variation during the switching cycle is strictly inversely proportional to the circulating current, and thus, by making the circulating current sufficiently large, any desired smoothness of operation can be secured. A convenient way of expressing the exact amount of voltage variation is to give this value for the case when the circulating current is exactly equal to the load current, under which condition the voltage variation will be 25 per cent of the voltage between adjacent taps, when no interlacing exists between reactor halves and 50 per cent of tap voltage for perfect interlacing between reactor halves. In general, therefore, reactance volts variation during the switching cycle varies between 25 per cent and 50 per cent of tap voltage for 100 per cent circulating current, the exact amount depending upon the degree of interlacing existing between reactor halves.

Comparison with Other Methods of Obtaining Ratio Control

The methods used for the purpose of limiting the circulating current distinguishes the various tap changing schemes. As a contrast to the methods particularly described in this paper, a few of the other existing methods may be mentioned. For example, in some cases, the current limiting device is designed to carry current only during the switching interval, in which case a pair of extra switches for the purpose of short circuiting the current limiting device must be provided, which is opened and closed in the right sequence during the switching process.

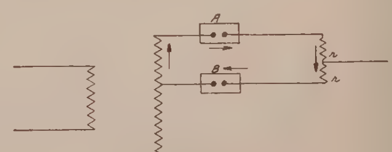


Fig. 5

In another case, an induction regulator is used to limit circulating current and at the same time to derive finer adjustments of voltage between relatively coarser taps.

Whatever method is used, the electrical performance will not differ greatly. Any one of the schemes can be made to cover as wide a range of voltage, and in as many steps, as desired. However, they differ very widely from each other in the kind of apparatus used and in the mechanical details by which the proper sequence of operation is controlled. In some devices the function of making and breaking current is separate from the function of transferring from tap to tap, special devices being employed to perform these func-

tions whereas in other cases, the one device is used to do both. Another difference in design consists, on the one hand, of using existing standard equipment such as circuit breakers, contactors, ratio adjusters, or, on the other hand, to design a special switch gear for this purpose. Many gears of this sort have been built in the past and are in successful operation. The present tendency, however, is to use existing standard apparatus as much as possible in order to realize the benefits given by apparatus already in successful operation and being built in large quantities. These benefits are perfection in mechanical details and at the same time, reduction in cost.

Equipment

In selecting the most suitable combination of apparatus for obtaining ratio control in connection with large power transformers, the features given chief consideration were: First, to use, as far as possible, standard and well-tried apparatus. Second, to select this apparatus with a view to obtaining as wide a range of application as possible with a minimum amount of detail changes in the apparatus. Third, to make the equipment simple of operation and suitable for either hand or remote control.

With these considerations in mind, the following equipment was naturally selected:

1. Power transformers provided with the necessary taps;
2. Ratio adjusters mounted inside the power transformers;
3. Two sets of circuit breakers to supplement the ratio adjusters on account of their inability to rupture the current;
4. A mechanism which operates the ratio adjusters and circuit breakers in proper sequence.

In this equipment, the only new departure involved is the design of the operating mechanism and in this, by incorporating many of the well-tried details of the operating mechanism of induction regulators, new development was reduced to a minimum and greater reliability in operation was assured.

The general mechanical arrangement decided upon was to place the ratio adjusters within the transformer so as to reduce the outside wiring; to place the operating mechanism on its own frame, thus permitting it to be used in connection with any standard transformer tank, and to design the operating mechanism so as to be suitable for operation with mechanically or electrically controlled circuit breakers. By this means, standardization of equipment is obtainable without sacrificing flexibility in application.

In the companion paper by Mr. Bates, there is described in detail the application of these principles to specific cases. His paper not only illustrates how the application of the above principle was worked out in detail, but it also shows clearly the wide applicability of the general scheme.

ELECTRIC LOCOMOTIVE OF 7125 HORSE POWER SHOWS EFFICIENCY IN TRACK TESTS

The world's largest locomotive, an electric giant 152 feet long, weighing 1,275,900 pounds and with a rating of 7125 horse power, underwent its first running test May 14 on the Westinghouse electric test track.

Witnesses of the running tests of the locomotive, the first completed of 36 ordered by the Virginian Railway for its $15,000,000 electrification project between Mullens, W. Va., and Roanoke, Va., included representatives of the Virginian, the Pennsylvania, the Baltimore & Ohio, and the Pittsburgh & Lake Erie Railroads, the American Locomotive Company, the Baldwin Locomotive Company, the R. D. Nuttal Company, the Westinghouse Airbrake Company and the Westinghouse Electric & Manufacturing Company.

The huge locomotive, under its own power for the first time, demonstrated the marvelous efficiency of the electric locomotive. Tests of its acceleration and its various speeds; tests of regeneration, the remarkable ability of the electric locomotive to regenerate power while taking heavy coal trains down steep grades and to turn the power back into the transmission line; and tests of the power of the motors, were made. It was demonstrated that by locking some of the wheels and throwing power on others, the wheels could be slipped without injurious affect to the motors thus proving that whatever the exigencies of the occasion, the electric locomotive will be equal to them.

The Virginia locomotives are so large that it was necessary to build them in three units each so that the length of more than 150 feet could successfully negotiate curves, and otherwise be controlled efficiently. Each motive power unit has the Mikado of 2-8-2 wheel arrangement, the weight of the cab being approximately 425,000 pounds, so that the weight of the three cab road engines is 637.5 tons. Each driving motor has mounted at each end of the shaft a pinion which meshes with a flexible gear and the gears are mounted on a jack shaft, the power being transmitted from the gear centers to the drive wheels by means of side rods.

To provide for the application of greater power to the transmission system, the Virginian locomotives have been designed for either 11,000 or 22,000 volts between the trolley and rail.

The Virginian electrification contract was the largest ever awarded. The electrification includes 133.6 miles of route and 213 track miles. The power plant for supplying the 11,000 volt or 22,000 volt alternating current is rapidly nearing completion. A part of the overhead catenary structure has been installed and the remainder of the locomotives, after the first is delivered, will be shipped on a schedule of one or two monthly. It is expected that complete operation of this section will be started before the close of the present year.

The Oil Circuit Breaker Situation from an Operator's Viewpoint

BY E. C. STONE[1]

Member, A. I. E. E.

Synopsis.—*This paper is an outline of the oil-circuit-breaker situation from the operator's standpoint, particularly with reference to interrupting duty, as it appears today to the author. It is not an original study, but rather an assembly of previously existing information, and is arranged by topics with a view to bringing out a large amount of discussion, in the hope that it may result in further clarifying the very complex problem of interrupting electric currents.*

The topics taken up are as follows:

I Factors determining interrupting capacity, namely intensity and duration of the arc.

II-III Essential features of breaker design and their functions.

IV Factors affecting interrupting duty, with especial emphasis on effect on same of system and fault grounding conditions.

V Relations between interrupting ratings and costs.

VI Status of interrupting ratings with reference to maximum nature of such ratings and facts upon which they are based; relative ratings on different operating duties and desirable modifications in method of rating.

VII Applications, particularly possibilities for improved practise in future and necessity of adequate maintenance on all breakers in service.

At the 1918 Midwinter Convention of the American Institute of Electrical Engineers, a paper on "The Rating and Selection of Oil Circuit Breakers" was read by Messrs. Hewlett, Mahoney and Burnham. In this paper the manufacturers presented their interpretation of the A. I. E. E. standards on oil circuit breakers as they existed at that time and a discussion of the features involved in the selection of oil circuit breakers for use on the various power systems. Since that time, much additional experience has been gained in the design and operation of oil circuit breakers and a definition of interrupting duty has been added to the standardization rules of the A. I. E. E.

In that which follows, no attempt at original research into the problem of oil circuit breaker interrupting duty has been made. Rather, the purpose is to present briefly, a bird's-eye view of the circuit breaker situation from an operator's standpoint, as it appears to the author today. It is hoped that the outline which follows, of some of the more prominent phases of the subject, will call forth discussions which will bring out much important information.

The rating of an oil circuit breaker includes normal voltage, normal current, normal frequency, maximum momentary current which the breaker can withstand and interrupting capacity. Of these items, all except the last are perfectly simple and not subject to argument. Hence, interrupting capacity is the only item of rating which is involved in the following discussion.

I—Factors Determining Interrupting Capacity of Oil Circuit Breakers

The interrupting duty imposed upon an oil circuit breaker when it opens a circuit depends on:

(a). Intensity of arc between contacts, which is a function of magnitude of current interrupted.

(b). Duration of arc, which is a function of the voltage tending to maintain the arc; that is the "recovery voltage" which appears across the terminals of the switch at the moment the arc is interrupted.

The effect of the arc is to release an amount of energy in the tank which is determined by the intensity and duration of the arc, as stated above. This energy appears as heat which breaks down a portion of the oil in which the contacts are submerged. Gases are emitted, which develop high pressures, and carbon is deposited, causing loss of insulation strength of the oil. Also, the contacts are usually more or less burned. If, due either to too great intensity of arc, (excessive current) or too great duration of arc (excessive voltage), or both, excessive amount of energy is released, the breaker will be unable to withstand the pressure developed and will give way, accompanied by more or less severe explosion, due to which the oil may ignite. The maximum amount of energy which the breaker safely can take care of marks the limit of its interrupting capacity.

After a breaker has opened the circuit, the gas pressure disappears in a comparatively short time, as the gas escapes through the vent, but the burning of contacts, carbonization of oil and depositing of carbon on insulated surfaces inside the tank are accumulative. That is, every time a circuit breaker opens a circuit through which current is flowing, the arc produced causes burning of contacts, oil carbonization and carbon deposit which effect a definite reduction in the interrupting capacity of the breaker. After a sufficient number of circuit openings, interrupting capacity of the breaker is exhausted and can only be restored by repairing contacts, cleaning inside insulating surfaces and replacing old oil with new.

The loss of interrupting capacity of a breaker, as it operates, may be likened to loss of capacity in a storage battery as it discharges. After a certain duty has been performed the breaker, like the storage battery, becomes exhausted. As the duty is intensified, the life

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1. Planning Engineer, Duquesne Light Co., Pittsburgh, Pa.

Presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

of the breaker is shortened; just as the life of the battery is shortened on heavy load duty. Again, just as the battery may be recharged after its life has been run, so a breaker can be brought back to its original rating by a little simple and inexpensive maintenance.

II—Essential Features of Oil Circuit Breaker Design which Determine Interrupting Capacity

The essential features of design which determine interrupting capacity are:

a. For interruption of arc—

Contact break distance.
Speed of contact travel.
Contact pressure.
Magnetic blow-out effect.

b. For absorption of energy of arc (gas pressure)—

Volume of oil.
Oil head above contacts.
Air space above oil.
Venting.

c. Mechanical Strength—Great mechanical strength is required throughout to withstand the strains due both to pressures developed by release of gas and to electromagnetic effects of the heavy currents handled.

d. Thermal capacity—All current-carrying parts must have sufficient thermal capacity to carry the maximum currents while they last.

Operating tendency is to require increased thermal capacity to take care of the longer duration of short-circuit current due to the higher relay settings used for obtaining selectivity of circuit-breaker operation and for taking advantage of the current decrement curve of the synchronous equipment.

e. Oil quality—

III—Design Features on which Difference of Opinion Exists

Opinion is divided as to the value of the following design features:

High Speed contacts.

Explosion chamber.

Multiple contacts in series.

Resistance introduced into breaker circuit to reduce energy released by arc in breakers.

Opinion is also divided as to the best means of absorbing the gas pressure and the different designs take care of this feature by various methods.

IV—Factors Determining the Interrupting Duty to which an Oil Circuit Breaker is to be Subjected

Since interrupting capacity depends on current interrupted and recovery voltage, the interrupting duty in any case varies with these two factors:

1. Factors affecting current to be interrupted: The maximum current which a circuit breaker may be required to interrupt is obviously a dead short circuit at its terminal.

The current at any point of a system, under short-circuit conditions, is affected by the following factors:[2]

a. The total kv-a. reactance, and transient characteristics of the synchronous machines connected to the system.

b. Number, reactance, resistance, capacitance, and arrangement of all circuits over which power can be supplied to the point of short circuit.

c. The kv-a. arrangement, resistance, reactance, and capacitance of all reactors and transformers, through which power can be supplied to the point of short circuit.

d. Contact resistance at the short circuit.

e. The nature of the short circuit, whether single-phase or multiphase.

f. The kv-a. and power factor of the load being carried at the time of short circuit.

g. The point of the pressure wave at which the short circuit was established.

h. The use of automatic voltage regulators.

i. Conditions as to grounding of system neutral and grounding of short circuit.

j. Elapsed time from first cycle of short circuit to interruption of arc on breaker contacts.

2. Factors affecting recovery voltage. Very little consideration, so far, has been given to these factors although they are fully as important as those affecting current. The most obvious are:

a. Phase angle between interrupted current and recovery voltage.

b. Conditions as to grounding of system neutral and grounding of short circuit.

c. The kv-a. and power factor of the load existing at the time of short circuit.

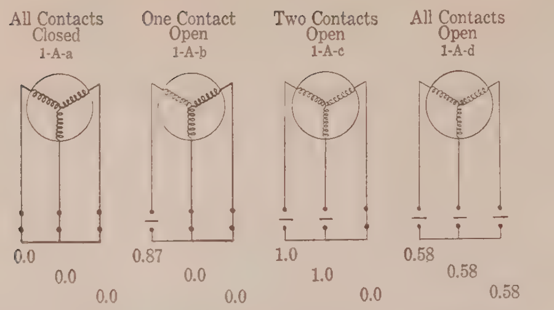
d. Arrangement and characteristics of circuits and apparatus.

The effect of item (a) has been discussed in a previous paper[3]. Under ordinary operating conditions item (c) should not vary sufficiently to affect radically the interrupting duty of the circuit breakers. The effect of Item (d) is to cause a high frequency transient voltage to be superimposed on the normal frequency recovery voltage, as a result of the discharge of stored energy in the system. Comparatively little data are available on the magnitudes of these transient voltages under varying system conditions—in most cases, however, it does not seem probable that they will increase the interrupting duties on breakers beyond the factors of safety intended to be in the breaker ratings.

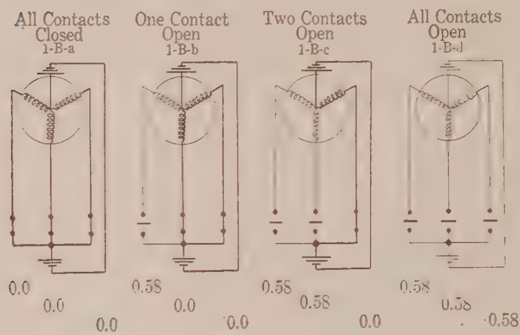
Conditions as to grounding of system neutral and grounding of short circuit, item (b), however, have very marked effect on the recovery voltage and therefore

2. Items (a) to (h) listed herein are taken from the paper "Rating and Selection of Oil Circuit Breakers" by Hewlett, Mahoney and Burnham, A. I. E. E., 1918.

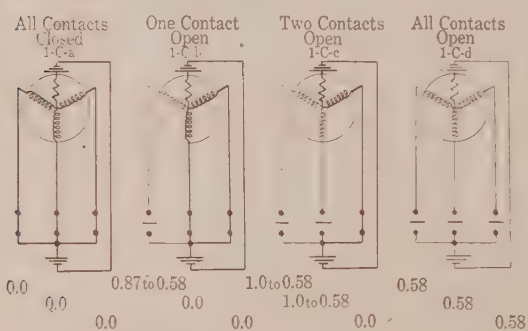
3. "The Rating and Selection of Oil Circuit Breakers" by Hewlett, Mahoney and Burnham, A. I. E. E., 1918.



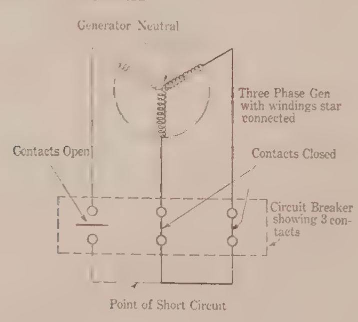
1A. Generator Neutral Grounded or Ungrounded Fault Ungrounded



1B. Generator Neutral Solidly Grounded Fault Solidly Grounded



1C. Generator Neutral Resistance Grounded Fault Grounded



1D. Explanation of Diagrams 1A to Ac

Fig. 1—Relative Recovery Voltages for Various System Conditions

In Figs. 1A to 1C the numbers directly under the breaker contacts give the normal voltages, expressed in decimals of normal system line voltage, which will exist across the respective contacts under the conditions shown. Under usual operating conditions, these values may be assumed as the limiting normal frequency recovery voltages on which interrupting rating should be based.

The parts of the circuit in which short-circuit current flows are shown by heavy lines.

on the interrupting duties imposed on the breakers. The relative values of recovery voltage under the various possible grounding conditions, are shown in Figs. 1a to 1c.

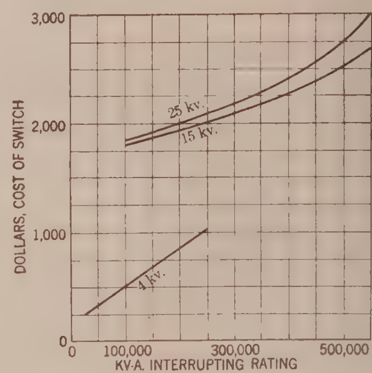


Fig. 2—Cost vs. Interrupting Rating for Oil Circuit Breakers. 25 Kv. and Below

V—Relation of Rated Voltage and Interrupting Capacity to Cost of Oil Circuit Breakers

For the study of problems in economics of system design a series of curves showing comparative costs

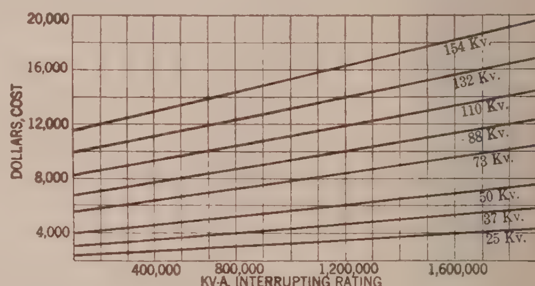


Fig. 3—Cost vs. Interrupting Rating for Oil Circuit Breakers, 25-Kv. and Above

of oil circuit breakers has been compiled. These curves are based on present day prices and are believed to present a fairly accurate picture of the relation of

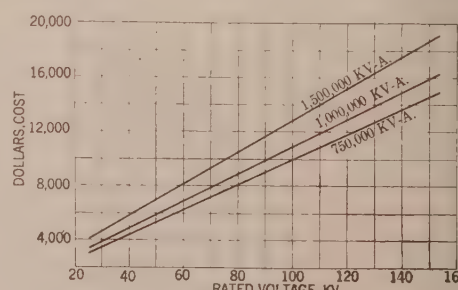


Fig. 4—Cost vs Voltage Rating for Oil Circuit Breakers Interrupting Ratings 750,000-Kv-a. to 1,500,000-Kv-a.

costs to interrupting ratings as a whole, although in some individual cases the price of a given breaker may be considerably out of line. These curves are shown in Figs. 2, 3 and 4.

On low voltage breakers interrupting capacity is the chief factor in determining price, while voltage has less effect. Thus, a 15-kv. breaker of 300,000-kv-a. interrupting capacity costs approximately 16 per cent more than a 15-kv. breaker of 130,000-kv-a. capacity, while a 25-kv. breaker of 500,000-kv-a. capacity costs approximately only 9 per cent more than a 15-kv-a. breaker of the same capacity. (Fig. 2.)

On high voltage breakers, however, voltage is the chief factor in determining the price, while interrupting capacity has a lesser effect. Thus, a 37-kv. breaker of 1,500,000-kv-a. capacity costs approximately only 28 per cent more than a 37-kv. breaker of 750,000-kv. capacity, but a 73-kv. breaker of 750,000-kv-a. capacity costs approximately 60 per cent more than a 37-kv. breaker of the same capacity. (Fig. 2.)

VI—Status of Interrupting Ratings

Interrupting ratings of oil circuit breakers are admittedly maximum ratings so that breakers cannot be expected to function properly even slightly beyond their ratings. It is understood, however, that these ratings are based on interrupting an ungrounded short-circuit, under which condition the normal frequency recovery voltage is a maximum. (Fig. 1A.)

Interrupting ratings are based on a constantly increasing fund of knowledge resulting from tests in factory and field and from operating experience. Special attention is called to the exhaustive factory tests made by one manufacturing company. Some of the interrupting duties under which breakers have been tested in the field are shown in Table 1.

TABLE I

FIELD TESTS ON OIL CIRCUIT BREAKERS OF HIGH INTERRUPTING CAPACITY

Normal Line Voltage	Limiting Recovery Voltage	Maximum kv-a. three phase Interrupted	Amperes per Pole	Grounding Characteristic: System Neutral	Grounding Characteristic: Short Circuit
	(See Note)				
132 kv.	77 kv.	725,000	3150	Dead Grounded	Grounded
110 kv.	63 kv.	542,000	2850	" "	Grounded
44 kv.	44 kv.	280,000	3660	" "	Ungrounded
44 kv.	25 kv.	246,000	3220	" "	Grounded
24 kv.	14 kv.	580,000	14,000	" "	Grounded
23 kv.	23 kv.	450,000	11,400	Grounded through Resistance	Grounded
13 kv.	7.5 kv.	545,000	23,700	Dead Grounded	Grounded

Note: Limiting recovery voltage, as used in above table, is defined as the maximum or limiting normal frequency recovery voltage which can appear across the contacts of one switch pole after the arc is interrupted, under the grounding conditions existing in the test. For explanation of method of obtaining these values see Figs. 1A to 1D.

On the actual tests the recovery voltage did not in any case reach the full limiting value as given above, even taking into account such higher frequency harmonics as were developed.

So far as the writer has been able to ascertain, no field tests have been made where more than 725,000-kv-a. has been interrupted. Most of these field tests, as shown in the table, have been made on grounded short-circuits in systems with dead grounded neutral. In such cases the recovery voltage is approximately only 58 per cent of that on a system with neutral ungrounded or grounded through a high resistance. The interrupting duty under such tests was therefore only about 58 per cent of that which would have been imposed if the tests had been made on systems with high resistance instead of dead grounded neutral. In general, also, tests were made under conditions where the transient voltages resulting from the interruptions of the short circuit have been very small, but on the other hand, metallic short-circuits were used, which would give more severe conditions than probably exist ordinarily in service.

Oil circuit breakers, with their designs based on the results of tests within the range of their interrupting rating, may be expected to perform satisfactorily up to these ratings, where they are installed under system conditions similar to those under which the field tests were made, particularly in regard to conditions as to grounding of system neutral and grounding of short circuits which the breaker must interrupt.

For ratings beyond the range of tests, it must be clearly borne in mind that very little direct data have been obtained and that designs are based on data deduced from tests made on lower interrupting duties. It remains to be seen how accurate the conclusions thus drawn will prove to be.

In oil circuit breakers for high voltages, the tank size is determined by the voltage rather than by interrupting duty. It is quite possible that the interrupting capacity of high voltage breakers may prove to be larger than expected for this reason.

All published interrupting ratings are now based on the standard operating duty approved last year by the Protective Devices Committee and printed in the A. I. E. E. Journal for October, 1924.

Referring to the standard definition of interrupting rating on which the standard operating duty is based, it is probable that the term "Normal Voltage" will require further definition in view of the wide differences in the recovery voltage which may prevail with the same normal system voltage. Meanwhile it is assumed as stated above that this term is interpreted to mean that the switch will be able to perform its full operating duty under the conditions which will give a recovery voltage up to the magnitude which results when the short circuit is ungrounded. It is not clear, at the present time, whether this is always the case.

Further attention must also be given to the relative interrupting ratings of the same circuit breaker under different operating duties.

The following relative ratings have been proposed by the Power Club:

a. One-unit operating duty...... 100 per cent to 125 per cent
Rating varies between limits given with design of breaker.

b. Two-unit operating duty, two-minute intervals (*standard duty*).......................... **100 per cent**

c. Four-unit operating duty, two-minute intervals	70 per cent
d. Four-unit operating duty, one-half minute intervals	60 per cent
e. Four-unit operating duty, no time intervals	25 per cent
f. 300-unit operating duty, 15-minute intervals	30 per cent
g. Four-unit operating duty, successive intervals of 0, 30, 75 seconds	30 per cent
h. Four-unit operating duty, successive intervals of 15, 30, 75 seconds	40 per cent
i. Three-unit operating duty, one-minute intervals	70 per cent

It is recommended that operating duties (d), (e), (g) and (h) be confined to oil circuit breakers having interrupting ratings on standard operating duty not over 250,000 kv-a. and voltage ratings not over 37 kv.

Taking the above figures as a basis, it is probable that a breaker that will perform satisfactorily under operating duty (a) or (b), one or two interruptions, will also perform satisfactorily on any of the other operating duties at the percentage rating given. On the other hand, it does not seem at all certain that a breaker which will satisfactorily interrupt the lower values of kv-a. on multiple interrupting duty will also be able to interrupt the higher kv-a. of the one or two interruption operating duties on the percentage relation shown in the table.

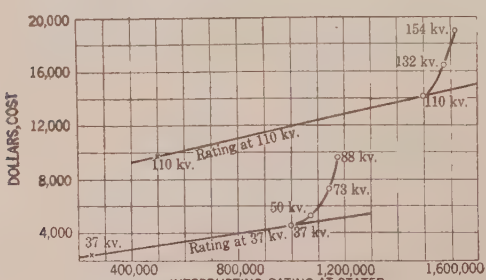


Fig. 5—Comparative Costs of Interrupting Ratings in Oil Circuit Breakers Operated at Voltages Below Normal

In Fig. 5 are shown the relative costs of obtaining interrupting capacity when using breakers at voltages below their normal rating. Thus, while a 37-kv. breaker of 1,150,000-kv-a. interrupting rating will cost $5000, a 73-kv-a. breaker, giving the same interrupting rating on 37-kv. operation, will cost $7300, an increase of 46 per cent. The effect of this relation of ratings is to make very much more expensive the use of breakers of higher-voltage ratings than the normal operating voltage of the system in which they are connected, although such practise becomes vitally necessary on some systems. Certain operating data which have come to the attention of the writer lead him to believe that in many cases the permissible increase in interrupting ratings at reduced voltage operation is too conservative and it is earnestly suggested that the manufacturers give careful consideration to revision of their present standards in this respect.

Tests are still urgently needed to prove performance at greater interrupting capacities and it is hoped that the operating companies will continue the practise of testing oil circuit breakers at progressively greater interrupting duties as the available short-circuit capacity on their systems increases. To assist in carrying out these tests and to provide for getting the greatest benefit from results obtained, a proposed uniform procedure for testing the interrupting rating of oil circuit breakers was approved by the Protective Devices Committee at its meeting last spring. This procedure now has the approval of the Electrical Apparatus Committee of the N. E. L. A. and is recommended as a basis of procedure for all future oil circuit breakers tests on power systems.

VII—Application of Oil Circuit Breakers

In considering the application of an oil circuit breaker to a specific situation, the maximum interrupting duty must be determined by calculation of maximum current to be interrupted and maximum recovery voltage. The interrupting rating of the breaker specified will depend upon the maximum interrupting duty as thus determined and the particular operating duty which will be demanded of the breaker in service. At the present time conservative practise requires that calculations be made on a basis that will give a maximum interrupting duty equal to or somewhat higher than that which can actually be imposed on the breaker.

Calculation of short-circuit current is thoroughly understood and can be made with almost any desired degree of accuracy.[4] Calculation of recovery voltage is not so well understood. The important factor to be taken account of in determining recovery voltage is the condition as to grounding of system neutral. (Refer to Figs. 1A to 1C). Up to the present time most of the heavy-duty oil circuit breaker experience has been derived from systems with dead, or nearly dead, grounded neutrals, on which the interrupting duty for a given current is of the order of only 58 per cent of that on a system with ungrounded or high-resistance grounded neutral. Hence on systems of the later type, which are becoming more numerous all the time, it becomes of prime importance to give careful consideration to the more severe conditions.

Up to the present time comparatively little attention has been given to refinement in the application of oil circuit breakers. As the interrupting ratings of breakers become more accurate it should be possible to fit breakers more closely to their individual duties. Many factors under operating conditions tend to make the current which must be interrupted on most faults of much less magnitude than the maximum current of a

4. "Application of Decrement Factors in Short Circuit Studies" by W. R. Woodward, *Electrical Journal*, May 1924.

dead short circuit at the breaker terminals. Some of the more obvious of these factors are:

Resistance in fault.

Faults resulting in grounds or three-phase shorts, whereas duty may be calculated on the more severe single-phase line to line short.

Neglect of system resistance in calculating fault currents.

In networks, the interruption of the fault in two or more steps.[5]

When these factors are known and circuit breaker ratings are also accurately determined, it may be found that the maximum conditions assumed in the selection of the breaker, at the present time occur so seldom that they may be treated as a special case. This special treatment might involve allowing the breaker to function above its rating in these few instances, or by prescribing a less severe operating duty under especially heavy short circuits, or by installing breakers in group arrangement in such a manner that one breaker of sufficient interrupting capacity to meet maximum duty would be in series with a number of smaller breakers designed for average conditions and would only open when the rating of the small breakers was exceeded by the short circuit. All of these methods are in use to a limited extent at the present time, but their effectiveness is uncertain, because of lack of exact knowledge as to conditions. Data on actual values of fault currents as experienced in every day operation, are much needed, and it is believed that if such data could be obtained and analyzed, material savings in overall circuit-breaker investment might be effected without undue hazard to service.

A number of companies have found it necessary to use breakers designed for normal voltage higher than those of the systems on which they are to be used, in order to obtain adequate factors of safety against insulation failure. On the basis of ratings now standard, this factor of safety is obtained only at marked increase in cost. (Fig. 6.)

The standard definition of operating duty of a circuit breaker contemplates very clearly that after the rated interrupting duty of the breaker is performed, the breaker is no longer good for its rating until suitable maintenance has been performed. The reasonableness of this condition is found in the explanation in Section I above, of what happens within the breakers when a current is interrupted. It is of the utmost importance

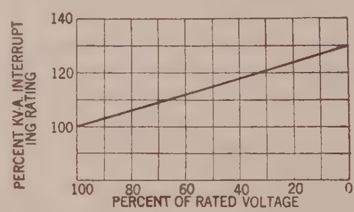


Fig. 6—Increase of Interrupting Rating of an Oil Circuit Breaker when Operated at a Voltage Below its Normal Voltage Rating

that this limitation be recognized. An adequate system of inspection and maintenance must be set up if satisfactory service is to be obtained. In this connection it is obvious that the cost of maintenance will be less where the rated interrupting capacity of the breaker is in excess of the maximum duty it is called upon to perform. In circuit-breaker installations, therefore, some consideration should be given to striking a balance between first cost and maintenance cost. Due consideration of both of these factors will sometimes call for a larger breaker than would otherwise be specified.

5. See discussions on papers on Baltimore tests, especially that by A. F. Bang, A. I. E. E., 1922.

Discussion at Midwinter Convention

EFFECT OF FULL VOLTAGE STARTING ON THE WINDINGS OF SQUIRREL-CAGE INDUCTION MOTORS[1]

(Rylander)

New York, N. Y., February 9, 1925

R. E. Ferris: Mr. Rylander's paper is the result of one of a series of tests being carried on covering the general subject of the effect of vibration on the insulation and windings of rotating electrical apparatus.

Insulating material may be quite highly carbonized and still retain a fairly large percentage of its original dielectric strength, provided actual mechanical breakdown does not occur. In practically all applications, however, some movement will occur. It is, therefore, necessary to keep the operating temperature of electrical apparatus well below the carbonization point of the insulation used, and also to minimize as much as possible the vibration and movement of the winding.

To accomplish the latter, it is desirable to wind all coils as tightly as practicable in the slots and to support the end portions in such a way as to minimize the effect of any possible shrinkage of insulation.

Especially for the larger size induction motors, some form of mica insulation is best, at least for the slot portions of the coils, as this material stands prolonged high temperature with very little shrinkage, thus insuring tight coils over a long period of time. Where induction motors are wound with closely fitting end-windings, *i. e.*, with no ventilation, the problem of bracing becomes simpler, but at the same time the possibilities of higher temperatures are increased, and therefore, with this type of winding, Class "B" insulation would seem to give less chance for shrinkage and consequent movement than with Class "A" insulation; in other words, the type of insulation to be used, especially on the end windings is intimately connected with the type of ventilation and method of bracing.

In the paper under discussion, the author has shown, in a quantitative way, the movements of induction-motor windings under the application of full voltage, and in this way has been able to make an intelligent study of the necessary bracings for the windings of this type of apparatus. With the type of bracing on the motors under test, the author apparently found that the use of an auto-starter did not make a great deal of difference as regards the magnitude of coil movement. The effect of ring-

1. A. I. E. E. Journal, Vol. XLIV, February, p. 115.

supported coils over those without the support is quite striking.

I might add that as I understand Mr. Rylander, he has not stated that all motors can be started under full voltage regardless of the type of bracing. In other words, he has emphasized the fact that proper and adequate bracing is necessary in order to produce motors which may be started under full voltage or over-voltage, and also that it may not be possible to eliminate the auto-starter unless the windings are properly and adequately braced.

V. Karapetoff: I think we should all welcome this new method of testing actual mechanical stresses in windings, and I am glad, therefore, to see this paper presented. I only regret the appearance of the so-called "working formula" in it.

The "working formula" on the sixth page in Mr. Rylander's paper is entirely misleading in so far as conductors in slots are concerned. The general law is that the mechanical force is equal to $I_1 I_2 d M / d x$, where I_1 and I_2 are the currents in the two circuits, and $d M / d x$ is the rate of change of their mutual inductance with the distance. (See, for example, A. Russell, Alternating Currents. Vol. I, page 40). In a very special case of two infinitely long, straight conductors carrying equal and opposite currents, the mutual inductance happens to be such that its derivative with respect to x gives the expression quoted in the paper. But with rectangular conductors in a slot, with currents flowing in nearly the same direction, and with the magnetic field determined by the iron structure, the coefficient of mutual inductance is expressed by an entirely different formula and gives a different force. For similar reasons, the formula quoted in the paper does not apply to the end connections.

R. E. Doherty: Any one who has ever tried to visualize the leakage flux in the end winding of an induction motor will have sympathy with Mr. Rylander's method of attacking this problem as contrasted with the one proposed by Professor Karapetoff. Any one of us familiar with matters of this kind, can set up the equations which express the force between coils as a function of the rate of change of mutual induction with respect to coil movement; but I would like to see the man who can apply it. Therefore, while I have the greatest respect for the wholesome and healthful effect of Professor Karapetoff's exhortation on us practical engineers toward making our treatment of practical problems a little more rigorous (we can improve it much), I nevertheless wish to express my sympathy with Mr. Rylander's practical point of view. It is necessary in many cases simply to take the larger factors involved (such as, in this case, that the force is proportional to the square of the current) and depend upon tests to determine the proportionality factors.

However, it may be that Mr. Rylander's equations can be improved to this extent: I notice that the formulas written down are for steady-state conditions. He simply balances the force exerted by the current and equates it to the force due to resilience to the coils.

I should like to call attention to the fact that this is a transient state, therefore, the accelerating force for the mass of the coils can not properly be neglected. Possibly if the effect of the mass of the coils were taken into account, it might possibly explain the discrepancy between the variation with the fourth power instead of the third power, as I believe he found in his test.

K. L. Hansen: In a paper entitled "The Starting of Polyphase Squirrel-Cage Motors" (JOURNAL A. I. E. E., Nov. 1923), B. F. Bailey discusses the effects of starting squirrel-cage motors by auto-starter, by resistance type of starter and by throwing the motor directly on the line. He considers the effects from four viewpoints:

1. Effect of starting current upon line voltage.
2. Affect upon connected apparatus.
3. Heating.
4. Power consumption.

Prof. Bailey has shown that in its effect on the voltage regulation the auto-starter offers practically no advantage over the resistance type and little advantage over direct connection to the line. This is especially true when it is necessary to use the higher voltage taps on the auto-transformer to get sufficient starting torque. With reference to possible injury to connected machinery, resulting from too rapid acceleration, there may be cases where throwing the motor directly on the line is less desirable than other methods, but such cases are rare. With reference to heating and power consumption Prof. Bailey showed that throwing the motor directly on the line is superior to both the auto-starter and the resistance type of starter.

To quote directly from Professor Bailey's conclusions:

"In view of the above facts it seems clear that it is entirely practicable to dispense with starters for polyphase squirrel-cage induction motors in a great majority of cases. No harm will come to the motor. The voltage regulation of the system in a majority of cases will be just as good as it was before and will be even better in the case of large installations"........

In his timely and interesting paper Mr. Rylander discusses the effects of various methods of starting from another very important standpoint, namely, the distortion of the windings. As pointed out by Mr. Rylander, the importance of movements and vibrations of the coils lies in the fact that they deteriorate the insulation, and, if sufficiently severe, will cause insulation failure. It, therefore, becomes of interest to observe whether or not throwing the motor directly on the line compared favorably with the auto-starter from this standpoint also.

One decided disadvantage of the auto-starter, clearly set forth in the paper, is that in going from low voltage to line voltage it is necessary to disconnect the motor entirely before reconnecting it to the line. The author states that during the moment of change-over the residual magnetism of the rotor induces a corresponding voltage in the stator, etc. This is somewhat misleading as by residual magnetism is usually understood the magnetism which remains in the magnetic circuit by virtue of hysteresis after the excitation has been completely removed. What he probably means to say is that the flux interlinked with the short-circuited winding of the squirrel cage cannot be instantly reduced to zero, because the decreasing flux induces a current in the squirrel cage tending to maintain the flux.

However, he is right in his conclusion that the voltage induced in the stator winding by the revolving flux of the secondary may be out of phase with the line voltage at the moment when the latter is applied, and that consequently there may be a heavy rush of current at this instant. That these large momentary currents are very undesirable from the standpoint of shocks to the windings is clearly brought out on the sixth page in the paper, where we read—

"Starting motors with full voltage produces a severe strain for a short period, whereas the use of an auto-transformer starter produces a less severe strain for a longer period and *also a momentary strain that may be more severe than when starting with full voltage.* The auto-starter may produce two severe shocks on the winding in opposite directions."

Thus the use of an auto-starter is liable to increase the severity of the shocks as well as the frequency with which they occur. Prof. Bailey's conclusion, that starters can be dispensed with in the great majority of cases, appears, therefore, to hold equally well, or even more so, when the effects of distortions of the windings are considered. The fact that auto-starters were used in the cases, mentioned by the author, where the insulation failed as the result of distortion of the winding, indicates that the starter is more of a liability than an asset.

The conclusions to be drawn from Mr. Rylander's experiments, taken in conjunction with the conclusions reached by Prof. Bailey, inevitably present the question, "Why are auto-starters, or compensators used in connection with starting of squirrel-cage motors, anyway?" No doubt it is desirable to reduce the starting current as well as to improve the starting torque of squirrel-cage

motors, but it seems that this can be much more effectively accomplished by other means than by an auto-starter. Quite a number of years ago Boucherot proposed the double squirrel cage as a means of obtaining good starting torque, low starting current and high operating efficiency. One reason for the slow adoption of the double squirrel cage may have been that the older methods did not lend themselves readily to this type of construction. However, a recently developed process of arc welding the rotor bars seems to be readily adapted to the construction of the double squirrel cage, and there are indications that the immediate future developments of squirrel-cage motors may be along this line.

F. C. Hanker: In connection with Mr. Rylander's paper, it is of particular interest to bring out a phase that has not been discussed. That is the elimination of the control in connection with power-house auxiliaries. This has been one of our most difficult problems because we have been confronted with sources of power far in excess of those usually found in the industrial installations. For that reason it has been very desirable to have a motor that could be thrown on the line at full voltage with satisfactory starting conditions and without control equipment other than the feeder oil circuit breaker.

The bracing of windings in the past has been largely controlled by experience in the field, and it is interesting to see the new point of attack, to observe the effects more accurately. The type of motor with the double squirrel cage gives reduced starting kv-a. and is applicable in cases where we are limited in the capacity available. In power houses we do not have that limitation and on those cases we can use the simple forms of motor with lower cost and just as satisfactory installation.

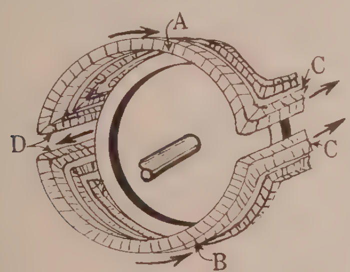


Fig. 1

H. Weichsel: A complete understanding of the forces acting on the windings of an induction motor when the machine is switched on the line is very important in view of the fact that the electrical engineers of many industrial plants are advocating the starting of squirrel-cage motors directly across the line. The investigation carried on by Mr. Rylander reveals many very interesting points, and in some cases apparently contradictory results. In the following an attempt will be made to give a physical conception of the forces acting in a machine during switching operation.

For simplicity's sake, an induction motor with a so-called chain winding in the primary member will be assumed. A large part of the free ends in such a winding is located parallel to the rotor surface. Another part, the so-called straight part of the free ends, is parallel to the shaft, as diagrammatically shown herewith in Fig. 1 for a two-pole machine. Only one phase of the chain winding is shown.

At any instant, the currents in the circular sections, A and B, of the free ends flow in the same direction. Therefore, the sections A and B will attract each other. The straight parts, C and D, of the coils carry currents of opposite directions. Therefore, a repelling action will take place between C and D. The forces C and D try to bend the coils outward, while the forces due to A and B try to move the coils inward. This assumes that a constant direct current is flowing through the winding. However, if it is a low-frequency current, then the coil will swing periodically, according to the change in the forces acting on the coils. If the frequency of the currents is high, the vibration of the coils will cease and change into a steady deflection. The inertia and spring action of the coils are playing an important part in determining which of the two results will be obtained.

This phenomenon is similar to the well known fact that the deflection of an a-c. dynamometer-type voltmeter is of a vibrating nature as long as the currents flowing through the instrument are of low frequency and with increasing frequency the swing of the needle becomes smaller and smaller and at a sufficiently high frequency the needle finally shows a steady deflection. Therefore, this example demonstrates a case where either a vibration or a definite deflection can be obtained, depending upon the relative relations of the impressed frequency and the natural periodicity of the deflected member.

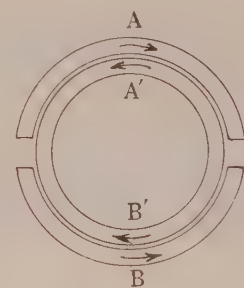


Fig. 2

It appears to me that this simple experiment gives an explanation of the fact that in Mr. Rylander's tests on the 50-h. p., 60-cycle motor a steady deflection of the coil was observed, while in the tests on the 500-h. p., 25-cycle motor a vibrating deflection was recorded.

In Fig. 1, we had assumed that the overall length of the squirrel-cage winding is considerably less than that of the stator winding and that, therefore, the current in the squirrel cage endings can not react materially on the free ends of the stator winding.

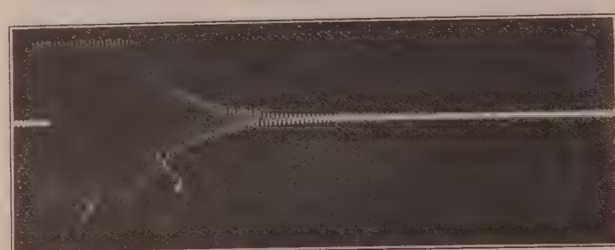


Fig. 3—Dying out of Terminal Voltage of a Squirrel-Cage Motor when Disconnected from Line

Fig. 2 represents a condition where the end rings of the squirrel-cage winding are approximately in the same plane with the parts A and B of the stator free ends. The current distributions in the ring and in the stator free ends are indicated by the direction and shape of the arrows.

The currents in the ring section A' and in the stator free ends A are in opposite directions and, therefore, a repelling action exists between these members. The straight part of the stator free ends is parallel to the free ends of the rotor bars and the currents in these members are equal but opposed to each other. Therefore, a repulsion exists between these parts also. The net result is that all parts of the stator winding have a tendency to move outwardly, a condition which has been observed in most of the tests shown by Mr. Rylander. This outward movement

naturally can either take place in form of a vibrating nature or in a steady deflection.

The forces acting on the windings will not vary in magnitude as long as the current's flow remains unaltered. At any moment the force acting is proportional to the square of the current. During switching operations, transient-current phenomena occur which may produce momentary current flows away above the steady current expected from the constants of the machine. This heavy transient flow may be the result of one of the two following features:

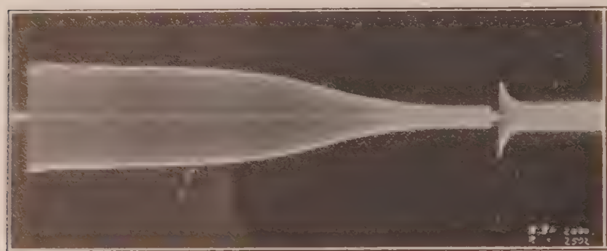


Fig. 4—Squirrel-Cage Motor Starting 22 per cent of Full Load with Auto-Starter

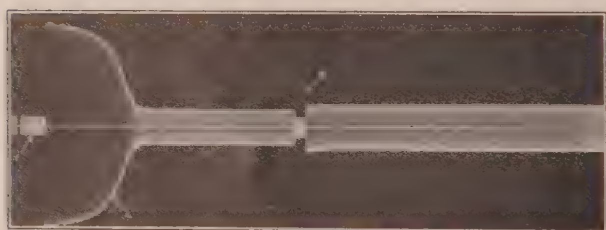


Fig. 5—Squirrel-Cage Motor Starting Idle with Auto-Starter

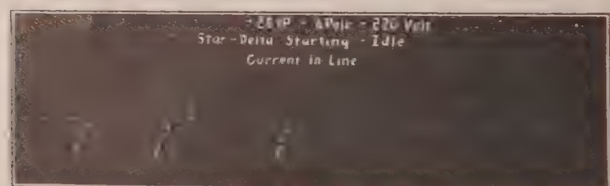


Fig. 6

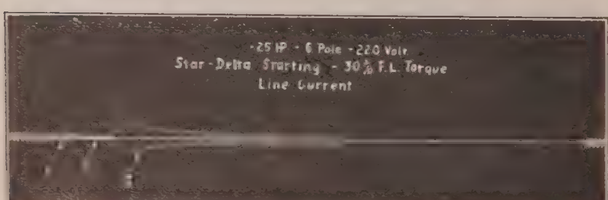


Fig. 7

1. When the motor is at rest, the first current inrush depends on the moment at which the motor is connected to the line in respect to the voltage wave on the line.

2. When the motor has been placed in motion by a supply of voltage and is then switched over to a different value of supply voltage, a very increased momentary voltage might act on the motor windings.

The case No. 1 is well understood and simply refers to the phenomena occurring when a choke coil is connected to an a-c. supply. The phenomena No. 2 are not as generally known.

If a squirrel-cage motor is running, let us say at synchronous speed, and the stator winding is suddenly disconnected from the line, then a voltage remains across the stator windings which gradually dies out, as given in the oscillogram Fig. 3. The reason for this remaining voltage is as follows:

According to the Lenz law, the magnetic field in a motor cannot disappear instantly. Therefore, at the moment the line is disconnected from the primary winding, currents will be induced in the rotor winding which try to maintain the original magnetic field of the machine. These are of direct current and gradually die out. The velocity with which they die out depends entirely upon the resistance of the secondary winding and the self induction of the machine. The decrease of the current and, therefore the decrease of the generating voltage occurs according to the well known logarithmic law, provided the speed of the armature remains constant.

Naturally the speed of the armature decreases gradually when the supply is disconnected and, therefore, the frequency of the voltage generated in the stator decreases with increasing time.

Therefore, if the line is reconnected to the motor shortly after it has been disconnected, it may occur that at the moment of reconnection the voltage generated in the machine is out of phase with the voltage impressed on the machine, which results in a very heavy current draw at the switching moment.

Oscillograms Figs. 4, 5, 6, and 7 show the heavy current inrushes which may occur during the switching period. As the

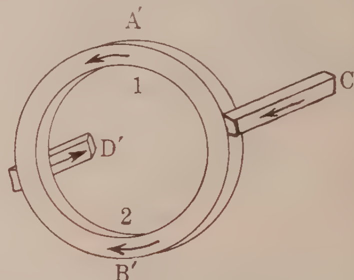


Fig. 8

forces produced by the currents are proportional to the square of the currents, it follows immediately from these oscillograms that the forces at the moment of switching might reach tremendous values and act like hammer blows on the windings.

It may be stated that these forces do not only act on the free ends of the windings but also act to produce torque on the rotor and incidently on the stator. I am familiar with cases where these torques reached such tremendous values that the stator iron shifted in the frame.

There are not only forces acting on the free ends of the stator winding in the manner discussed, but there are also forces acting on the free ends of the squirrel-cage winding itself.

Fig. 8 represents the current distribution in a squirrel-cage winding at a given moment for a two-pole machine. The ring sections, A'–B', carry a current of equal distribution flowing in the same direction. Therefore, an attraction occurs between these two sections, as indicated by the arrows 1 and 2. The extensions of the rotor bars, C and D, carry equal currents but in opposite directions. Therefore, a repelling force is created between these bars.

If we assume that the currents flowing in the rotor winding are direct currents, then the ring will take an elliptical shape under the influences of the forces just discussed. In a polyphase motor, the relative current distribution in the rotor bars and rings is the same at any moment but the picture of current distribution rotates. The velocity of rotation in respect to a given point of the

squirrel cage is proportional to the frequency of the currents flowing in the secondary. Therefore, the end rings on the squirrel cage will successively take shapes as indicated in Figs. 9A to 9E inclusive. This periodic deformation of the rings and bars is quite likely to lead to a fatigue of the materials and a final breakage unless the rings are properly supported to resist effectively the forces acting on it.

In a similar manner, if the stator coils are laced to a circular coil-supporting ring, the forces acting on all the windings have a tendency to deform the ring into an elliptical shape similar to the Figs. 9A to 9E inclusive. In order to counteract this efficiently, it is advisable to brace the coil-supporting rings in twice as many places as there are poles and give these brackets for the coil-supporting rings equal spacing. A coil-supporting ring with

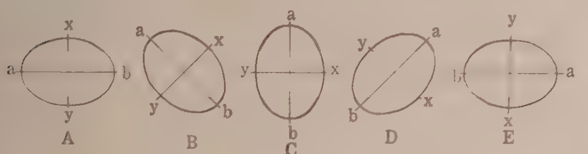


Fig. 9

semi-circular cross section and a piece of heavy insulating material on the straight part of the coil-supporting ring has proven to be more effective than a circular ring. The coil would touch the circular ring in only one point and the unavoidable vibration of the coil and ring is likely to wear the insulation through in relatively short time, while with the semi-circular ring the coil makes more of a line contact than a point contact with the supporting ring and, therefore, the possibility of wearing through the insulation is materially reduced.

Mr. Rylander pointed out that the deflection of the stator coils depends to a large extent on the length of the free end coils, but as the length of the free end coils is closely related to the arc spanned by the coils, it is possible to obtain simple empirical rules to determine when coil-supporting rings are needed.

My experience has shown that whenever the coil spans more than 8 to 9 in., it is absolutely essential to provide the stator winding with coil-supporting rings. The lower figure refers to 25-cycle and the larger figure to 60-cycle machines. This is

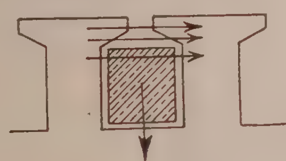


Fig. 10

explained by the fact that the 25-cycle machines usually have finer wire than the 60-cycle machines and, therefore, the coils have less rigidity.

Returning once more to the forces acting on the squirrel cage, the part of the bar which is located in the slots is subjected to a force due to the leakage lines passing over the bar, as indicated in Fig. 10. These magnetic lines have the tendency to push the bar inward, *i. e.*, in the direction towards the shaft. The force producing this tendency is proportional to the square of the current, *i. e.*, the force will reach a maximum whenever the current is of either positive or negative maximum, as given in Fig. 11. If the bar is not secured tightly in the slots, then these forces are apt to set the bar in vibration, swinging it around its two points of support on the two end rings of the machine, in the same manner as a violin string. This may result in a fatigue in the bar material at the point where the bar joins the ring with a consequent breakage. It is, therefore, essential to provide means to anchor the bars securely in the slots. Such arrangements can be made, for instance, by driving a wedge between the top of the bars and the lips of the rotor slots.

Mr. Rylander showed in his Fig. 11 that the time decreases rapidly with increasing starting voltage. In case the machine has to accelerate nothing but an inertia load, it can quite readily be proven that the starting time varies inversely to the square of the impressed voltage. If, however, a friction load is to be started in addition to an inertia load, then the starting time decreases still faster than the inverse of the square of the voltage. Therefore, it might quite readily occur that when starting a machine under full voltage the heating of the stator coils is less than when the same load is started with reduced voltage though such starting draws a heavier current than the reduced-voltage starting.

On the other hand, if a motor has sufficient starting torque to handle its load with reduced voltage, then the resistance of the squirrel-cage rotor could be reduced when full-voltage starting is employed. This would result in an increased running efficiency of the machine but also in an increased heating of the stator winding during the starting period.

Full-voltage starting, therefore, might finally lead to machines with somewhat increased running efficiencies by decreasing the rotor resistance. If, however, use is made of a decreased rotor resistance, the designer will have to safeguard against a saddle formation in the speed-torque curve. In other words, the machine will have to be designed more carefully.

J. L. Rylander: In regard to Mr. Hansen's comments about the auto-starter, it is well to mention that the type of auto-starter used was that which opens the circuit momentarily when chang-

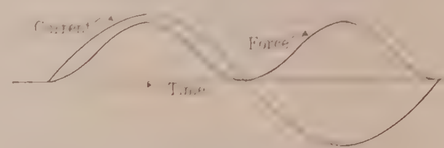


Fig. 11

ing from the low-voltage tap to the full-line voltage, as this is the most severe condition of the various auto-starters; and it was used for the purpose of finding out what happens when the circuit is opened momentarily before applying full voltage.

In regard to Mr. Weichsel's comments about the physical conception, I think the best physical conception is to keep in mind that like currents attract and opposite currents repel. We know the direction of the current and therefore we know the reactions.

In regard to Professor Karapetoff's remarks about the formulas, it should be added that the purpose of the formulas is to show the main factors involved and use them in conjunction with tests, or the known conditions of certain motors to which comparisons can be made. There are four main factors:

1 The shape of the coil.
2 The spacing.
3 The current.
4 The length between supports.

The shape of the coil is fairly constant and the coil movement is directly proportional to it; the spacing is fairly constant and the coil movement is inversely proportional to it. But these two points are not the dominating factors. The coil movement varies according to the square of the current, which varies considerably in the different motors, varying anywhere from four to ten times the full-load current. But the dominating factor is the length, which varies as the third or fourth power. For practical purposes, the main factors are sufficient and the best way is to use them in connection with that which is known.

We can watch any motor that we are acquainted with as it is started on the 50, 65 or 80 per cent voltage tap. Then if we compare that with the formulas, we can about tell what will happen when full voltage is applied. Or if we want to compare windings that are similar except for length, it is a matter of comparing the length of the coil extensions.

POWER-SYSTEM TRANSIENTS[1]

(Bush and Booth)

New York, N. Y., February 10, 1925

V. Karapetoff. The method of solution of the problem of power surges, developed by the authors, may be called that of solution of differential equations by finite increments. While in the paper the differential equations themselves are not written down explicitly, they are understood to hold true. These equations express the condition that an excess of mechanical energy, applied to a synchronous machine, partly accelerates (or retards) its revolving masses, partly is delivered to the bus through a change in the torque angle, and the rest is delivered to the bus through the asynchronous action of the damper winding[2]. This is expressed analytically as

$$(J/p)\,\Omega_m\, d\,\omega/d\,t + W_s\,(\theta - \theta_m) + W_D\, d\,\theta/d\,t = \Delta\, P \quad (1)$$

where the first term represents the rate of change in the stored kinetic energy in a rotating mass of moment of inertia, J, the second term represents synchronous power due to a change in the torque angle from its mean value θ_m to an instantaneous value θ, and the third term represents the power transmitted through the damper winding. The term Δ, P on the right-hand side, is the applied excess power which causes the surge. Such an equation may be written for every synchronous generator, motor, or condenser in the system. In addition, we have relationships of the form

$$d\,\theta/d\,t = \omega - \omega_k \quad (2)$$

where ω_k is the angular velocity of the vector of the bus vector and ω is that of the machine, both at the instant under consideration. For each bus, the value of ω_k is different because of the properties of the transmission line. For a section of such a line we may write

$$N\,(\omega_k - \omega_k') = \Sigma\, \Delta\, P \quad (3)$$

where ω_k' corresponds to ω_k at the other end of the line and N is the slope of a power curve, such as are shown for example in Fig. 10 of the paper. In other words, N is the rate of increase in power transmitted, per degree in the change of the angle between the receiver and the generator voltages.

All the equations of the types (**1**), (**2**), (**3**), form together a system of simultaneous differential equations which expresses the complex phenomenon of hunting within the limits of the assumptions made. Further equations may be added to take into account centrifugal governors, voltage regulators, machine transients, etc. While the foregoing equations are linear with constant coefficients, so that their solutions may be written down directly without much trouble, the purely algebraic complexity of these solutions makes them almost useless in all but the simplest cases.

The method of finite increments consists in taking small finite values, $\Delta\, t$, of time and computing the values of θ and $d\,\theta/d\,t$ at the end of each interval $\Delta\, t$. For example, at the first instant of application of $\Delta\, P$, we must put in eq. (**1**): $\theta = \theta_m$ and $d\,\theta/d\,t = 0$. Hence $d\,\omega/d\,t$ may be computed directly. Assuming this value of $d\,\omega/d\,t$ to remain constant over a small interval of time $\Delta\, t$, will give directly the values of θ and $d\,\theta/d\,t$ at the end of the interval. Substituting these values in eq. (**1**), a new value of $d\,\omega/d\,t$ can be computed, etc. Of course, the method is quite tedious, but is apparently the only one feasible if the results are to be derived by computation, and not experimentally.

Sometime ago the present writer proposed a similar method of solution for high-frequency transients on transmission lines and constructed a computing device to facilitate the actual obtaining of numerical results.[3]

F. C. Hanker: The problem of stability in power systems has become one of increasing importance as a result of the rapid increase of electric supply systems. In the early days, a great many of the troubles were caused by the variation in angular velocity due to use of reciprocating prime movers. It was found, however, that difficulty was experienced, even with turbine-driven units, in operating synchronous apparatus on transmission lines of high impedance values, and field tests made some twenty years ago at the suggestion of Mr. Lamme developed empirical data that were sufficiently accurate to meet conditions existing prior to a few years ago.

During the power survey made in 1920-1921 in the North East Atlantic States, studies of transmission of large blocks of power from the St. Lawrence indicated instability. Mr. Baum had been working on the same problem, and the analytical studies suggested the use of intermediate regulating stations. It was recognized that systems were operating satisfactorily under similar conditions when prime movers with drooping speed characteristics were driving the machines used for regulating purposes. There was some discussion, however, as to the stability of synchronous condensers operating in this way, and it was for the purpose of studying this and other important phases of the problem that the tests made in 1923 were conducted.

These tests were reported to the Institute in a group of papers presented at the 1924 Midwinter Convention. Since that time, we have continued our analysis of the problem, supplementing it with tests to develop data on specific phases. It is very reassuring to find that there is a very general interest in the problem, and that the importance of it is recognized. In addition to the studies that are being made from the standpoint of bulk transmission, the operating companies are making careful analysis of the conditions that exist in power systems. This will give us a great deal of fundamental data that will be extremely valuable as supporting the analytical work.

The authors state "There are only three ways in which knowledge necessary for proper judgment can be gained." It appears that they have overlooked one of the most important sources of information, and one in which the variables are considered in their proper relation. I refer to tests made on actual operating systems where the layout corresponds to the condition to be analyzed. A number of tests of this character have been made, more are now under way, and it is to be hoped that further tests will be carried on. The very active interest of the operating engineers in this problem, and their cooperation in carrying on these tests, give us the assurance that data necessary for supporting analytical studies will be available.

As the authors have pointed out, it is necessary in the theoretical studies, to make assumptions as to the characteristics of a number of the variables involved. It is this necessity in connection with analytical studies that makes it important that supporting data be made available.

The investigations that we have made have indicated that the single-phase short circuit with its subsequent switching is the most severe practical condition to be met in operation. Obviously, a system cannot be economically designed to insure continuity of parallel operation under a three-phase short circuit that would reduce the voltage on the interconnecting lines to zero. On extremely high-voltage lines, the construction is such that the occurrence of a short circuit involving all conductors is extremely rare and can be practically eliminated from consideration as the final criterion. In the present state of the art, single-phase faults from one conductor to ground are to be expected, and for such condition, we consider it reasonable that the system be designed to maintain continuity of service.

A short circuit to ground may involve a considerable increase in the true power demand on the generators, depending upon the location of the fault, and the ohmic resistance of the ground circuit. In our study of this problem, we find that under certain conditions, the usual method of governing by speed only increases the tendency to instability. It is desirable to reduce the

1. A. I. E. E. Journal, VOL. XLIV, March, p. 229.

2. E. Arnold, *Wechselstromtechnik*, Vol. 4, p. 384.

3. V. Karapetoff. Double Integraph for Electric Line Transients; *Sibley Journal of Engineering*, 1925, Vol. 39, p. 243: also the Bulletin No. 4 of the Engineering Experiment Station of the College of Engineering, Cornell University.

amount of power transmitted during a disturbance, and with the relation between generator inertia and line impedances found on long lines, sufficient time is available to effect this by closure of the waterwheel gates, provided the actuating impulse is started at nearly the same time the short circuit occurs. The control device to do this would probably be a relay operating on ground current, negative-sequence current, reactive power, or increment of true power.

Tests have been made on a large power system, which show that the oscillation produced by disturbances are damped out very rapidly, hence after the control point has been passed, the gate may be opened again, the whole operation lasting perhaps 15 seconds. The deficiency in energy at the receiver end of the line, due to the short circuit and partial closure of waterwheel gates, can be readily supplied from the kinetic energy of the rotating apparatus there, and by temporary overload of the steam plants.

We are making a study of the normal action of steam-turbine and waterwheel governors to determine their effect on stability, when they are grouped together at the receiver end of a line. Due to the large number of stations, it is impracticable to attempt to use any auxiliary control on the governors, and only their normal operating characteristics can be considered.

C. L. Fortescue: The authors of this paper have undertaken the difficult task of presenting in detail a step-by-step method of computing the effects of power transients in transmission systems. On starting to read this paper I was quickly conscious of the inherent difficulty of presenting a subject of this nature in a paper, and I can fully sympathize with them in these difficulties.

I have gone over this paper several times with some care and I believe I am safe in saying that it would require fully a week of careful study before anyone not thoroughly familiar with the authors own particular methods could apply them to the solution of transient problems. There are so-called short cuts that in my estimation save little time and are confusing to use as for example the arrangement illustrated by Figs. 3, 4 and 5. In my opinion the circle diagram without the other attachments would be much more understandable and just as easy to use.

We have made analyses similar to those described by the authors. Our, methods, however, are I think more direct and simple although they take into consideration all the factors which the authors have considered. I cannot help feeling that they have made a difficult problem still more difficult. Some of the statements in the paper are very obscure, as for example the statement regarding computations for condenser angle at the bottom of the first column on the eleventh page. My understanding of this statement is that the field current is determined on the basis that during the initial transient the magnetomotive force acting on the main field remains practically constant.

The proper way of presenting a subject of this kind is of course by direct example, that is to say, carrying out the computations step-by-step with the pupil and showing the method of superimposition actually. It may be as the authors state that in a description these methods appear to be more complicated than they really are.

I believe, however, that graphical superimposition methods, however appropriate they may be for illustrating the behavior of a system under certain abnormal conditions, do not lend themselves to accurate point-by-point analysis. In point-by-point analysis, the accuracy of each succeeding computation depends upon that of the previous one, consequently small errors become cumulative resulting in quite large errors in the final results and after all, the point-by-point computations are only steps leading up to the final result which determines whether the set up under the conditions assumed is stable or not.

I would like to point out that the circle diagram which the authors use is a simple modification of the circle diagram which we have used in the past. I am quoting verbatim from our paper of last winter's convention.[4]

"Proof of the Circle Diagram

"From this point a proof of the circle diagram is readily derived. The conjugate equations of (2) may be written:

$$\hat{I}_s = (\alpha - j\,B)\,\hat{E}_s - (\gamma - j\,\delta)\,\hat{E}_r$$
$$\hat{I}_r = (\gamma - j\,\delta)\,\hat{E}_s - (\alpha - j\,B)\,\hat{E}_r$$

"Multiplying I_s by E_s and I_r by E_r we obtain the power at generator and receiver respectively.

$$P_s + j\,Q_s = E_s\,I_s = (\alpha - j\,B)\,E_s\,E_s - (\gamma - j\,\delta)\,E_r\,E_s$$
$$P_r + j\,Q_r = E_r\,I_r = (\gamma - j\,\delta)\,E_s\,E_r - (\alpha - j\,B)\,E_r\,E_r$$

but $E_s\,E_s = E_s^2$ and $E_r\,E_r = E_r^2$.

If we let E_r be the datum line and $E_s = E_s\,\epsilon^{j\theta}$ then $\hat{E}_r\,\check{E}_s = E_r\,E_s\,\epsilon^{j\theta}$ and $\check{E}_r\,\hat{E}_s = E_r\,E_s\,\epsilon^{-j\theta}$. Substituting in above,

$$-P_s + j\,Q_s = (\alpha - j\,B)\,E_s^2 - (\gamma - j\,\delta)\,E_s\,E_r\,\epsilon^{j\theta} \qquad (4)$$
$$P_r + j\,Q_r = (\gamma - j\,\delta)\,E_s\,E_r\,e^{-j\theta} - (\alpha - j\,B)\,E_s^2 \qquad (5)\text{''}$$

Dividing (4) by E_s^2 and (5) by E_r^2

$$\frac{P_s}{E_s^2} + \frac{j\;Q_s}{E_s^2} = (\alpha - j\,B) - (\gamma - j\,\delta)\,\frac{E_r}{E_s}\,e^{j\theta}$$

$$\frac{P_r}{E_r^2} + \frac{j\;Q_r}{E_r^2} = (\gamma - j\,\delta)\,\frac{E_s}{E_r}\,e^{-j\theta} - (\alpha - j\,B)$$

A circle diagram which has many advantages is obtained by dividing both equations (4) and (5) by $E_s\,E_r$ giving

$$\frac{P_s}{E_s\,E_r} + j\,\frac{Q_s}{E_s\,E_r} = (\alpha - j\,B)\,\frac{E_s}{E_r} - (\gamma - j\,\delta)\,e^{j\theta}$$

$$\frac{P_r}{E_s\,E_r} + j\,\frac{Q_s}{E_s\,E_r} = (\gamma - j\,\delta)\,e^{-j\theta} - (\alpha - j\,B)\,\frac{E_r}{E_s}$$

Divide equation (4) by E_s^2 and equation (5) by E_r^2 and we have the two systems of concentric circles which the authors used. Moreover the angular relation between sending and receiving voltage is not lost, thus equation (4) says that the locus of $P_s + j\,Q_s$ is given by $\alpha - j\,B$ and the radius vector drawn from this point $-(\gamma - j\,\delta)\dfrac{E_r}{E_s}\,\epsilon\,e^{j\theta}$. The angle θ being the lag of $\dfrac{E_r}{E_s}$ over E_s, the data from which to measure being obtained by equating θ to zero.

I wish to say that when plain vectors are under consideration there is no excuse for using Cartesian analysis since an appropriate algebra for such vectors already exists, being merely the algebra of complex numbers. The only precaution necessary in dealing with electrical quantities represented by vectors is to remember that the vectors are not the actual quantities but merely represent them; the actual quantities are scalar and may be represented actually by the sum of two conjugate vectors. The advantage of the above method of analyzing the transmission power problem is that the angular relation between sending and receiving voltage is preserved and its relation to the power sent over this circuit is plainly seen.

While the authors have taken a great deal of pains to present a method of computing the behavior of transmission systems they have said very little in regard to methods of improving the behavior of such systems. While the Company with which I am connected has been quite busy in making extensive computations in connection with the stability of transmission systems they have been still busier in attempting to find means to improve the stability. The following is a brief résumé of some of the most promising means of accomplishing this.

(a) *High-Speed Excitation and Special Machine Character-*

4. *Some Theoretical Considerations of Power Transmission*, C. L. Fortescue and C. F. Wagner, A. I. E. E. Journal, February 1924, page 106.

istics. When a sudden load is thrown on a system there is an instantaneous drop in voltage at the load point. If a regulator can be obtained sufficiently sensitive with a high-speed exciter the field of the condenser or generator at this point may be kept from decreasing and actually increased. As an actual fact during the field transient the field circuit has no effective inductance and the only resistance the electromotive force of the exciter has to overcome is the resistance of the field itself, so that there is a decided advantage in quick action outside of the effect on stability. The same exciter if it were to operate after the field transient had died out would take very much longer to build up a field to the same value.

Special machines can be designed having characteristics which lend themselves to stability. The theoretical basis of this may easily be obtained by the consideration that generators, synchronous motors, condensers, etc., are merely extensions of the transmission line; their internal characteristics will therefore have considerable bearing on stability.

(b) *Intermediate Condenser Stations.* Intermediate condenser stations having condensers of suitable characteristics are essential for economic transmission over long distances. There are other advantages which cannot be measured in dollars but which may be more important. Properly chosen characteristics for the condensers may result in considerable increase in the stability of the system.

(c) *High-Speed Circuit Breakers.* In case of short circuit in any section of the transmission system it is advantageous to cut out the faulty section as quickly as possible. Where the fault occurs near the generating station due to the sluggishness of hydraulic governors the generators may fall in speed quite considerably before the circuit breaker opens. After the circuit breaker opens on regaining equilibrium there is a tendency to overshoot due to gathered inertia to such a point that the machine gets out of step. A sufficiently quick acting circuit breaker takes care of this condition very effectively and also will take care of most conditions of trouble arising in transmission systems.

(d) *Governors.* A complete paper could be written on steam and hydraulic governors and such a paper would I regret to say deal chiefly with their shortcomings. I feel that there is room for a great deal of improvement and such improvement will come by studying their characteristics in connection with the problem of stability.

(e) *Increasing the Number of Sectionalizing Points.* The shorter the sections of transmission line that are cut out due to a fault, the less effect the cutting out will have on stability. Therefore, increasing the number of sectionalizing stations will improve the stability of the system. There is, however, an economic limit to this method determined by the number of circuit breakers required for each additional sectionalizing station.

(f) *Neutral Impedances; Selective Impedances.* Since most of the troubles connected with transmission lines are due to grounds, power stability may be preserved by the introduction of neutral impedances or resistances. The objection to this method of preserving stability is the tendency to produce voltage transients in the transmission system endangering insulation and apparatus. Since most short circuits are single-phase or unsymmetrical therefore an impedance which will impede the negative-sequence component of current without offering impedance to the positive-phase component of current will help secure stability.

In our study of the problem of stability we have attempted to steer a course between analytical methods and practical experiment. Since the analytical solution at its best is very involved, one can hardly expect engineers of utilities or technical advisers of syndicates to accept the results without some practical backing. We are preparing papers to be presented shortly before this Institute showing our method of analyzing these problems but we prefer to hold back this information until we can get actual data in the field, substantiating our results. Tests are under way now to procure this data and so far results appear to be very promising. I may say that the results indicate that all the investigators of stability under transient conditions including ourselves have been too pessimistic. I am glad to say that we have been the least pessimistic and are therefore more nearly right.

I wish to emphasize that in a problem so involved as in the one that the authors treat of, analytical solutions alone carry very little weight and they must be backed by actual practical demonstrations on existing circuits. Demonstrations without artificial transmission lines and models are not satisfactory. The method of point-by-point analysis using an artificial transmission line described by Messrs. Spencer and Hazen offers a great deal of promise. There is also a possibility of working out kinematical models which will embrace all the essential elements of the problem. I think that work along these lines should be encouraged. I think a machine is much more adaptable in working out problems of the character than a human being.

F. G. Baum: The problem of stability is one that has been with us for more than twenty years. If you will examine the TRANSACTIONS of the Institute of twenty odd years ago you will find a great deal of space taken up by discussions of the question of hunting of synchronous motors, and the hunting between parallel stations.

The problem as presented by Professor Karapetoff was covered, I think, as early as twenty odd years ago, and for those of you who haven't followed the transmission work particularly and who wish to study it, and to begin in an elementary way, I suggest you look at a paper published in the *Electrical World*, March 29, 1902 on "Synchronous Motor Stability and Overload Capacity Curves." You will find there many of the curves given by Messrs. Booth and Bush. They are curves given in pecentage of voltage, percentage of current, and so forth, so they are applicable for any scale that you wish to take, whether it is 110,000, 150,000 or 220,000 volts or something beyond that.

It has been my pleasure and privilege to be connected with transmission work for nearly thirty years, and I have found the subject so interesting and so broad that I haven't done much of anything else. But the transmission has been rather a disappointing part of the system, I may say, until within the last few years. It seems as though transmission was always lagging behind the power-station work. The power stations and the transformers were always ahead of the transmission lines. We never could get the capacity over the transmission lines that it would appear to be necessary, from the demands of the power stations and the power-consuming loads.

About five or six years ago, realizing that that condition confronted us, I made a study of the 220-kv-a. system. And I must say that the first time I ever got a real kick out of making transmission calculation was when I calculated a 220-kv-a. system; for it appears that for the first time we have a transmission system that is commensurate with the generators, and the large-size generators, water wheels, transformers, and loads required at the present time.

As I say, realizing that five or six years ago, I recommended that we build a 220-kv-a. system to bring power from the northern part of California down to San Francisco, for I realized that without a high-voltage system of this kind it could not be economically done.

In a large system like the Pacific Gas and Electric Company, many problems of stability are solved by Nature. For example, on our system for about twenty years we have not operated with all the governors on the system trying to take hold of the load. You can not do that, but you eliminate and block the governors, and one or two stations at the most become the clearing house for kilowatt-hours. That simplifies your governor operation very materially and resolves it, then, to an infinite bus practically and a smaller unit with a fluctuating load.

With the 220-kv-a. system, it is necessary to operate with

condensers on the system. You cannot do it without them. That makes it possible to simplify the operation to a very much greater extent, for just as we have one or two stations furnishing a clearing house, so to speak, for the kilowatt-hours, we have one or two stations furnishing a clearing house for the kv-a.

It is the lagging kv-a. that pulls the power system, and if you can prevent that lagging kv-a. from pulling the voltage out of the system, and if you can keep the actual kv-a. necessary to maintain the reaction pressure tangent to the voltage circle, you are not going to have instability. It is impossible to have instability with the current and pressure in phase. It is only when they get out of phase, at cross-purposes, that you get instability.

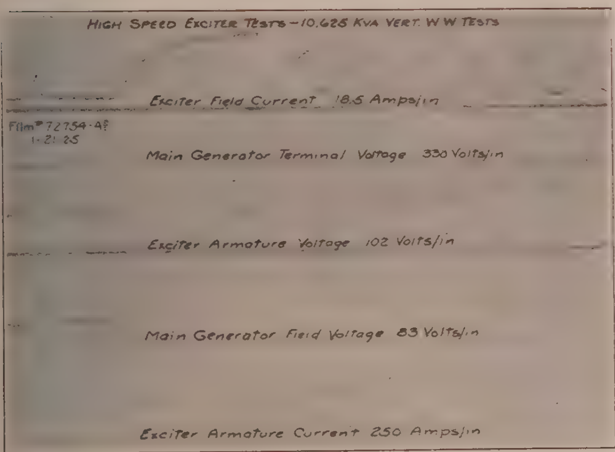


Fig. 1

Finally I may say this: it appears, that now for the first time we have a transmission system which is commensurate with the needs of the industry, but apparently we also have a transmission system that is inherently suited to outdoor operation. It appears, that we can never defy the lightning or the weather conditions in other respects.

C. F. Wagner: The authors of the paper mentioned the subject of high-speed excitation but have not stressed its importance sufficiently. I wish to emphasize high-speed excitation as a means of improving the stability of long-distance power transmission systems.

Introducing the effect of generators and condensers reduces the ability of the system to withstand disturbances as compared with the line alone. Suddenly increasing the lagging current drawn from an alternator or condenser increases the demagnetizing effect. The flux, however, cannot change instantly. At the first instant current is induced in the field windings and eddies in the pole pieces of such magnitude as to overcome this demagnetizing effect. The eddy currents in machines without damper windings are relatively small and to simplify the discussion will be neglected. The voltage required to circulate the additional field current is supplied by the change in flux through the field windings and is equal to the increment of IR drop in the field circuit. With hand regulation the flux will decrease until the total IR drop in the field winding is again equal to the exciter voltage. In effect, a hand-regulated machine introduces an artificial internal series reactance although it is in part compensated by the larger artificial internal voltage.

The voltage coils of automatic voltage regulators of the Tirrill type are connected across the terminals of the generator. On sudden application of lagging load the internal-drop reduces the terminal voltage which in turn closes the regulator contacts and increases the exciter voltage. If the exciter voltage could be built up instantly to such value corresponding to the new IR drop of the field currents the flux would remain constant. Actually, however, the exciter voltage builds up along a very definite curve. During the interval while the drop in the field winding is greater than the exciter voltage, the flux in the main machine decreases in a manner similar to that discussed for hand regulation. The flux will continue to decrease until the exciter voltage is equal to the drop in the field windings. An excess of exciter voltage over IR drop increases the flux.

From the foregoing it can be seen that the faster the exciter voltage increases the smaller will be the decrease in flux. This is what the high-speed exciter attempts to accomplish. Note particularly that the high-speed exciter relies not upon changing the flux in the main machine but rather upon annulling the effect of the armature demagnetizing current. Of course, the slower the field of the machine the smaller will be the flux change, but if the increase in exciter voltage is always of such value as to annul very quickly the effect of any reactive current that might reasonably occur then it would be more desirable to have a fast field and a high short-circuit ratio.

Fig. 1 is an oscillogram taken during some tests on a 10,625-kv-a. 100 rev. per min. alternator in which 4350 kv-a. leading load was thrown off. This simulates the condition of suddenly increasing the lagging load as would be the case during short circuits. Dropping leading load simultaneously decreased the terminal voltage. After an interval due to the lag in the regulator and relays the exciter voltage begins to increase as shown. This lag can be made practically zero by arranging an extra pair of contacts in parallel with those of the regulator and operating them from the fault ground current or from reactive kv-a.

The rest of the story is self-evident. The loss of magnetizing armature current induces an equivalent current in the field winding. This current decreases for an interval but the rapidly increasing exciter voltage soon annuls this action and increases the field current. In the meantime the terminal voltage is increasing with the field current until a voltage is reached which causes the regulator contacts to separate. The exciter voltage decreases and after a series of oscillations settles down to normal no-load conditions.

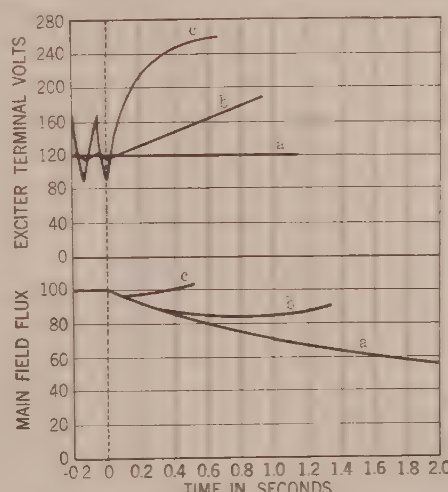


Fig. 2—Effectiveness of High-Speed Exciter in Maintaining Flux in Alternator

Armature current suddenly increased from zero to 100 per cent, zero power factor lagging.

a. Hand regulation
b. Standard exciter with Tirrill regulator
c. High-speed exciter with Tirrill regulator

The effect of high-speed excitation upon the flux is better illustrated in Fig. 2. These curves were prepared from test data and indicate the change in exciter terminal voltage and flux of main machine as the armature current is increased from zero to rated-value zero power factor. Curves marked a represent

the conditions for hand operation, curves marked b for standard exciters and curves marked c for high-speed exciters. The load was applied at an instant when the exciter voltage had reached a minimum value to represent approximately the worst condition. For hand operation the flux decreased enormously; with the standard exciter the decrease was still quite considerable; but with the high-speed exciter the decrease was negligible. With this type of excitation transient conditions may be calculated using the assumption of constant flux through the field windings, *i. e.*, that component of flux in phase with the rotor. It should be noted that high-speed exciters do not control the cross flux, this being a function of armature current only.

While it is true that the stability of a high-voltage transmission system can be increased by the application of high-speed exciters with fast regulators of the Tirrill type, its utility is not universal, in fact quite the contrary. Their application to generators connected to transmission lines in which the resistance is about equal to or greater than the reactance decreases the stability. For this case hand regulation or slow-speed exciters and rheostatic regulators are preferred. In this connection it should be noted that the general stability of a system cannot be increased by speeding up the excitation of synchronous equipment at the end of distribution lines, which usually have high ratio of resistance to reactance as compared with high-voltage transmission lines.

In the event of a disturbance which unbalances the voltages such as a line-to-ground fault, it is of course necessary that the regulator contacts close and remain closed. This may not occur if the regulator is connected in the usual manner. Rather than decreasing the voltage of the phase to which the regulator is connected analysis has shown that the disturbance might increase the voltage. Proper action can be insured by connecting the regulator through a network which passes only the positive-sequence voltage.

High-speed exciters increase the duty on circuit breakers, but this is probably not an insurmountable difficulty.

R. C. Bergvall: Mr. Hanker and Mr. Fortescue have pointed out that ordinary switching operations are not the limiting conditions which have to be met in considering stability. The limiting condition is the ability of the system to remain in synchronism during short circuits and during the switching operations following the abnormal conditions set up by the short circuits. Experience has shown that line-to-ground short circuits constitute about 90 per cent of the system disturbances and particular attention must, therefore, be paid to maintaining stability under these conditions. With two systems tied together by two parallel transmission lines, it is practically impossible to maintain synchronism if a three-phase short circuit occurs near the generating station or the substation, because the voltage on the tie line is reduced to zero. Various methods have been considered in an effort to increase the possibility of maintaining synchronism, such as rapid relay operation or making the transformer a unit with the line as Mr. Thomas proposed at the 1924 Midwinter Convention, thereby interposing the transformer reactance between the bus and the short circuits. However, in most cases the necessity for flexibility in switching of the high-tension lines makes it impossible to lay out the system in this manner.

The engineers of the Westinghouse Company have been actively investigating the effect of line-to-ground short circuits during the past year. The importance of making such investigations can best be seen by considering a line-to-ground short circuit having 5000 amperes of ground current. This corresponds to a loss of 25,000 kw. per ohm of ground resistance, which is an appreciable kilowatt load to throw on a system already carrying a heavy load.

The magnitude of the ground resistance is an indeterminate factor. A bushing circuit on a transformer would have practically zero ground resistance while a tower located on rocky soil would have considerable ground resistance. The worst condition would be some value of ground resistance between the zero ground resistance and the extremely high ground resistance, provided it was desired to maintain stability under all line-to-ground short circuit conditions.

The problem of determining stability in the case of line-to-ground short circuits is complicated by the presence of unbalanced currents and voltages and by the opening of circuit breakers before the steady-state condition has been reached. When the circuit breakers open the entire load is immediately transferred to the other transmission line and pull-out is likely to result because of the sudden change in load at the same time that the system conditions have been disturbed by the short circuit.

The calculation of single-phase short-circuit currents by the commonly used methods on an extensive transmission network is difficult because the currents and voltages are unsymmetrical and each phase is inductively coupled in the transmission lines, transformers and rotating machines. Furthermore, all rotating machines, provide a distinct phase-balancing action which tends to restore symmetry in voltage and current. A solution of a problem of this type is to be published by R. D. Evans in a future issue of the *Electric World*. Essentially it is an application of the method developed by C. L. Fortescue for the general solution of unbalanced polyphase circuits. Briefly, the voltages and currents of the three-phase grounded-neutral circuit are resolved into the positive-sequence, negative-sequence, and zero-sequence components, which do not react upon each other and may be considered independently. With normal balanced loads only positive-sequence voltages and currents are present, but in the case of a short circuit to ground all three sequence components are involved.

The method employed in investigating the possibility of pull-out occurring during line-to-ground short circuits consists of substituting equivalent impedances in the circuit to represent the zero-sequence and negative-sequence components, thereby leaving only the positive-sequence components which may be handled by the usual methods.

S. B. Griscom: As has been already pointed out in the discussions certain disturbances on transmission systems, notably the single-phase, line-to-ground short circuit with the subsequent line switching may produce large oscillations in the phase position of the generators about the angle corresponding to their mean output. The system must be designed so as to withstand disturbances which are of common occurence. This means that the maximum operating load must be considerably less than the power limit of the line. On the other hand, economic considerations demand the transmission of the maximum power possible per dollar of transmission investment.

Two general courses of action are available to increase the economy of transmission. The theoretical power limit of the line may be increased by proper design of the line, including the associated apparatus, or the effect of disturbances can be reduced, enabling a smaller factor of safety to be chosen.

The group of papers presented in February 1924, and the discussions on them, considered in a general way the use of synchronous condensers located at points along the line for the purpose of increasing the amount of power that could be transmitted over the circuits. This scheme was first proposed by F. G. Baum, in a paper before the A. I. E. E., in 1921.

We have since made an extended study of this system which has shown its utility. For transmitting a given amount of power over a line, a certain amount of reactive power must be supplied to it depending on the voltage conditions. The usual method is to supply this at the two extremities of the line; by the generators at one end, and by synchronous condensers at the other.

On long lines it is necessary to sectionalize at one or more points, so that in event of trouble, it will not be necessary to cut

out too large a proportion of line. These sectionalizing points are ideal locations for the installation of synchronous condensers, since switch structures and attendants are already there.

By installing condensers at these points, the maximum operating load may be increased, and the voltage regulation at intermediate points greatly improved. This is especially desirable for future interconnections or loadings at intermediate points.

The theoretical limit of a long line may be made to approach the limit of the longest section between points where synchronous machinery is installed, depending upon how well the machines can maintain the line voltage. By the use of machines designed with this object in view, and by using a high-speed exciting system in conjunction with them as mentioned in one of the discussions the regulation can be made very good.

Our studies have shown that it is economically possible to increase the permissible load on a 250-mi., 220-kv. line about 25 per cent by means of suitable installation of synchronous condensers at intermediate points.

The other general method of increasing the carrying capacity of transmission circuits is to lessen the effect of short circuits in causing pull-outs between supply and receiver ends. One method which shows considerable promise is to use an auxiliary control on the governing mechanism, as has already been mentioned. Another method under consideration is to use circuit breakers on the main transmission circuits, which would operate at speeds considerably higher than those in use at the present time. The utility of this scheme is readily apparent when we consider that if the breaker could be opened at the instant of short circuit, the condition would be in effect only that of line switching, which is much less severe.

Up to the present time, no data is available as to the maximum speed that can be attained by circuit breakers in interrupting large currents at 220 kv. In order to get an idea of what can be gained by using different speeds of circuit breakers, some calculations were made on stability during single-phase-to-ground short circuits, when the faulty section of line was cut out at different time intervals from the instant the short circuit occurred. The results of these calculations are presented in the form of curves, showing the variation of angular position of the generator rotors with time, for a typical transmission system.

By referring to the accompanying curves, it will be noted that if the circuit breaker opens at the instant of short circuit, there is very little relative movement in phase position of the rotors of the generators with reference to the load. If the short circuit is permitted to hang on for 0.2 seconds, a somewhat greater swing takes place. For 0.4 seconds, the swing is of such a large magnitude that on the second half cycle of mechanical oscillation the systems pull apart as indicated by the fact that the angle continues to increase with time. The same is true with any time of breaker opening up to 1.0 second. From 1.0 to 1.6 seconds stability can be maintained. From these curves, it is evident that if the period of oscillation is of the order of one second, the stability of the system can be greatly improved by the use of sectionalizing circuit breakers which open the circuit within 0.2 seconds after a short circuit occurs.

If the natural period is greater, a correspondingly higher maximum time is permissible. These curves show clearly the element of chance, due to erratic relay or breaker operation, and explain why a short circuit may cause pull-out on one occasion and not on another when conditions are apparently identical.

Aside from the question of lessening oscillation of the generators and other synchronous machines, the use of high-speed circuit breakers would be of material assistance in minimizing voltage decrement due to demagnetization. On this account, their rupturing capacity must be increased, although the use of a special excitation system might independently impose this requirement.

It may be somewhat premature to mention the use of high-speed circuit breakers of this type, when none have thus far been developed, but the principle purpose of this discussion is to point out possible methods for improving stability.

V. Bush and R. D. Booth: A number of the discussions treat of improvements of transmission system and correlated apparatus and need no further comment in connection with a paper devoted to methods of analysis.

Prof. Karapetoff's discussion is an admirable presentation of the fundamentals upon which the methods of the paper are based, and undoubtedly adds completeness and clarity to the entire subject. It might, however, be in order to point out that the differential equations used by Prof. Karapetoff are linear and also that the coefficient N,—the rate of increase in power transmitted per degree change of the angle between the receiver and generator voltages—is constant. The methods presented in the paper permit analysis of those problems in which the equations are non-linear, and the coefficients are not constant.

Mr. Baum's discussion of the progress of the art of transmission and of operation of systems involving long transmission lines is of general interest. We presume that Mr. Baum refers to steady-state rather than transient conditions when he says that practically infinite bus conditions at the sending generators can be obtained by blocking the governors thereof.

Mr. Wagner's discussion of the possible benefits of high-speed exciter systems and Mr. Griscom's studies of the advantages of high-speed circuit breakers are of great importance to the industry. We presume that Mr. Griscom's curves of desirable operating times apply only to a particular system and for particular values of arc resistance. Also we presume that Mr. Wagner's discussion of the limitations of high-speed exciters is based upon specific data regarding arc resistances and operating times of breakers and governors.

Discussion at Spring Convention

EIGHT YEARS' EXPERIENCE WITH PROTECTIVE REACTORS[1]

(Lyman, Perry and Rossman)

St. Louis, Mo., April 14, 1925

J. Lyman: To obtain the minimum concentration of power is an everpresent problem in the design of large power stations, substations, and distribution systems. A circuit breaker must be built, capable of opening its circuit, under any short-circuit conditions, but more serious than the problem of designing adequate circuit breakers are the electrical and mechanical shocks that may be transmitted to the entire electrical system from a modern bulk-power station, or to a power distribution and transmission system, tying-in several such great stations. At least 0.3 sec. elapses before a circuit breaker can operate. During this time the full force of the shock is imparted to the entire system.

As the units of power to be controlled are continually increasing, the design of circuit breakers capable of controlling them is becoming more and more important. The combination of current-limiting reactors with the circuit breakers in such a way that a minimum concentration of power is secured without materially affecting voltage regulation should, therefore, be the aim in the design of power stations and distribution systems. Thus electrical and mechanical impacts due to electrical disturbances of whatever nature, will be kept down to a minimum consistent with successful operation and the greatest reliability of service secured.

1. A. I. E. E. Journal, Vol. XLIV, June, p. 60.

Reliable and efficient power stations, transmissions and distributions are rapidly bringing to a reality universal 60-cycle power throughout the country. Clearly in any electric power system the latest, most economical power station should be operated as a strictly base-load plant. In this way the lowest possible cost per kw-hr. is obtained and advantage taken of the remarkable advances in power-station design.

By judicious location of synchronous condensers and reactors, voltage regulation can be maintained and power drawn from any power station over the entire system.

In general, the energy losses in the synchronous condensers are compensated for by the improved efficiency of transmission lines, transformers and generators, supplying power at the higher power factor, while the capital costs of the synchronous condensers are more than offset by the increase in capacity of the system at the higher power factor. Thus, it is possible to operate with reliability the latest power plant on the system as a base-load plant with the resultant system economies. By so doing the electric power can be supplied over a wide radius to the large industrial plant or to an electrified steam railroad at a lower price than that at which these companies are able to make power because they have a comparatively fixed power demand at a comparatively low load factor; thus when their power stations become obsolete, they cannot write them off their books and discard them. They cannot take advantage of the improved efficiencies of the latest power-station design and of the high load factor that is obtained on an extended improved power system.

H. W. Eales: Mr. Rossman has called attention to the remarkable fact that it is possible for short circuits to occur within power stations and for the operating staff to be unaware of the fact. Mr. Rossman mentions a short circuit of this nature at Windsor Station.

About twelve years ago, one of the 11-kv. busses burned in two in the Keokuk Station. For some time the operators there were unaware that they were delivering single-phase power over the 143-mi. transmission line to St. Louis.

In December 1924 a short circuit occurred in one of the bus chambers at Cahokia Station and although the operator knew that a short circuit existed on the system he did not ascertain for several minutes that it was within his own station although it later developed that it was located on the same floor on which the operating benchboard is situated.

As a result of that and other experiences we have recently concluded to install in Cahokia Station an indicating and ground-current protective system.

We believe that, with the isolated-phase arrangement of oil circuit breakers and other accessory equipment as now completely installed at Cahokia Station, a three-phase short circuit is virtually an impossibility. In designing the indicating and protective system about to be installed, it is necessary to consider only protection from phase to ground.

A review of all cases of trouble which have involved the station bus revealed that in order to clear the short circuit it was finally necessary, by manual operation, to isolate the bus section in trouble and disconnect its generator and other sources of power connected to it. This consumed valuable time during which system service suffered. As long as it is necessary to do this ultimately, it has been decided to arrange for its accomplishment automatically and instantly.

The method to be employed will consist of introducing current transformers in the apparatus ground bus ahead of the connection to earth. The secondary leads from these current transformers will be brought to the benchboard operating room to relays whose operation will cause the lighting of telltale lamps indicating the bus chamber in which the short circuit occurs, and simultaneously cause the opening of the bus-section circuit breakers, at both ends of the bus section involved, open the generator breaker or this bus section, and also tie feeders, if any, from other stations or systems.

E. C. Stone: The determination of the arrangement of bus reactors in a power plant must take into account both the protection of equipment and the safeguarding of service. Of the five cases of bus-reactor operations reported in this paper, three apparently resulted in complete shut-down of the power plant and consequently serious interruption to service. In my opinion the bus reactor problem is not solved until service as well as equipment is completely protected.

H. R. Summerhayes: I have had occasion to review and analyze most of the major bus short circuits that have occurred in large power stations, and it appears in nearly all of them that if the bus section could be segregated instantly from the rest of the station, matters would be better than they are. That is to say, some service might have been lost, but not nearly so much service as has been lost in most of these short circuits. Therefore, I am heartily in favor of some system of protection, which will sectionalize the bus. It has been accomplished by the differential protection used in the Brooklyn Edison Company's system and in the hydroelectric plant at Queenston, Ontario. In the latter, I believe the differential protection has actually worked successfully several times. It is also accomplished by the ground protection system mentioned by Mr. Eales.

The ground protection system is simple and it is based on the probability that nearly all bus troubles on the isolated-phase system, or on the group-phase system, involve a ground, and there is some ground current flowing.

It is very simple, then, to connect all of the non-current-carrying metal in the vicinity of a bus section and the switches pertaining thereto through a current transformer to ground. Instead of connecting them all to the common station ground, we run all the ground connections from switch bases, operating mechanisms, etc., of one bus section through a current transformer to the station ground, and that current transformer is made to trip the section switches, feeder switches and the generator switches on that bus section, and do so instantly. In this manner the service can be resumed with the least amount of interruption.

While reactors are very effective in limiting short-circuit currents, there is one trouble that has been encountered with the use of bus reactors, namely, when a large amount of current is being passed over a bus reactor from one section to another, the bus voltage differs on the two sections, or rather there is a phase difference which unbalances distribution of load in feeders from different bus sections to the same substation. To prevent this unbalance it is desired to make a reactor which will be of low reactance at normal load, and high reactance at short circuit; this has been the aim of inventors for a good many years.

I hope that that problem will be solved; that some form of linkage will be found which will enable a large amount of power to be exchanged between bus sections or generating stations under normal conditions and will interpose a high reactance instantly before one cycle is passed when short circuit occurs.

F. H. Kierstead: This record of eight years' experience with a variety of reactors and only one instance of a reactor failure (and in this instance, the fault appears to have been with the installation and not with the reactor) is, I think, a positive testimonial of the reliability of modern current-limiting reactors. However, I, personally, am not satisfied with even the fine record that reactors have made, but feel that we must press on toward a still higher degree of the perfection of this device upon which we depend to protect everything else in great power systems. This greater perfection must come not alone from increased efforts on the part of the manufacturers but also through a better understanding of the characteristics of reactors by the operators and from more consideration being given by them to the installation and upkeep of the reactors.

Turning to the record in this paper, it is to be noted that in the one case of a reactor failure the reactors pulled together because they had not been bolted down to the floor. Now I am

not bringing up this point in order to excuse a reactor failure, (the reactors were not of our manufacture, but the results would doubtless have been the same had they been our reactors, if the means which we provided for bolting the reactors to the floor had not been used); nor do I bring it up in order to point out a faulty installation, but I am bringing it up for consideration because it illustrates my point that a better understanding of the characteristics of reactors is required and more consideration must be given to their installation in order to obtain a higher degree of perfection in the service that they render. It should be clearly appreciated that there is a large magnetic force between adjacent reactors when carrying short-circuit current and that for this reason reactors should always be bolted to the floor and, in many cases, must be further braced to withstand this force.

There is another source of danger to reactors which I think is worthy of consideration at this time. It is one which we all should realize but one which many of us overlook. I refer now to the failure of a reactor which may be caused by foreign conducting material accidentally dropping into a reactor and lodging in the winding. We have proven, by careful tests, that if a piece of metal, such as a screw, bolt, nut, or washer becomes lodged in the winding and escapes notice during inspection, no indication of its presence in the reactor will usually be given during the normal operation of the circuit because of low voltage between turns, but at the instant a short circuit occurs, when the voltage between the different sections of the winding jumps to many times its previous value, incipient arcs shoot out where the metal bridges across a section of the winding and are followed instantly by a complete flash-over of the reactor. Our tests have further proven that thin insulation on the conductor will not prevent such failures, even though the insulation has ample dielectric strength to withstand the voltage placed across it by a short circuit for the reason that the magnetic force exerted on iron and steel objects will cause them to break through thin insulation.

This danger may be eliminated by a very careful inspection of the reactor before it is placed in service in order to be sure that no such foreign material is lodged in the winding. The inconvenience of making such an inspection should not deter one from making it for it is in those places most difficult to inspect that foreign material is most likely to lodge.

Attention is further called to the fact that the magnetic field of a reactor carrying a short circuit will reach out to a distance at least equal to the diameter of the reactor and draw loose magnetic material into its winding. Therefore, great care must be taken to keep the passageway where reactors are installed clear of such material. Doors or screens across the openings of the compartments in which reactors are installed are recommended as a means of preventing any such material which may be dropped in the passage-way from getting into the reactors.

For those installations where it is very difficult to be sure that foreign material will not enter into the reactors and for those operators who require a safeguard from it in addition to that afforded by inspection, The General Electric Company has developed a thick asbestos insulation which is closely and firmly woven on the reactor conductor and is treated with flame-proof compound which makes the covering very strong and able to resist cutting and tearing very tenaciously. This insulation is used solely to prevent foreign material causing a short circuit between turns. The special grade of Portland cement concrete supports so successfully used for years is still the major insulation. Reactors with this insulation have been thoroughly tested by making many short-circuit tests upon them with a 26,700-kv-a., short-circuit testing generator and these tests have proven that this insulation affords adequate protection to the conductor from foreign material and that the insulation is so free from any inflammable material as to be properly classed as fireproof.

H. W. Osgood: This timely paper is a valuable confirmation of the effectiveness of reactors placed in a ring bus in large generating stations. Reactors placed in a bus between generating units are more effective for limiting short-circuit current than reactors of greater reactive voltage drop placed in series with the generators and in effect paralleled on a bus. Reactors of moderate size are also necessary in the generator leads as these give to the generator circuit and the busses protection equivalent to that provided by feeder reactors.

In looking up earlier information on use of current-limiting reactors, we find that in June, 1909, Mr. Junkersfeld presented a paper at Atlantic City, before the National Electric Light Association on "The Use of Reactance Coils in Generating Stations." In this paper, mention was made of the first application of reactors in the Cos Cob Station of the New York, New Haven and Hartford Railroad, an installation in the Central Station at Baltimore and in the Fish Street Station at Chicago. Reactors of the choke-coil type had, however, been used on many overhead and a few underground circuits prior to these installations in Cos Cob, Baltimore, and Chicago.

Dr. Steinmetz, in his discussion of that paper in 1909, said among other things, "When you come, however, to still larger stations—and some of the largest stations in the country are rapidly approaching that condition—then we meet the condition where even with this generator reactance, limiting the momentary short-circuit current to about ten times full-load current, the rush of current at the bus bars is altogether too much to permit a switch to be designed economically to take care of it, and then we shall be obliged to carry the limitations still further in the manner suggested by Mr. Junkersfeld, in sectionalizing the bus bars by reactance. This suggestion is therefore not an alternative to the generator reactance but is in addition thereto, for those cases of huge powers—200,000 kw. or more—where the generator reactances are no longer sufficient to limit the momentary short-circuit current at the bus bars to a reasonable value; that is, to half a million or a million kilovolt-amperes."

During these 16 years since this discussion by Dr. Steinmetz, the rupturing capacity of oil circuit breakers has been increased, in some cases, to 1,500,000 kv-a., but the ultimate capacity of generating stations has been increased in some cases to a projected total of 600,000 kw. Current-limiting reactors have therefore become indispensable between bus sections, as well as in the generator leads and feeders to limit the short-circuit current, within the rupturing capacity of circuit breakers.

The isolated-phase arrangement with vertical separation of phases is peculiarly adapted to the installation of current-limiting reactors. Space is afforded in the switchhouse where the generator leads come up or the feeders drop down to the cable tunnel, the bus structures and oil-circuit-breaker compartments being grouped in the center with an operating aisle between structures. With the reactors isolated in this manner there is less likelihood of a phase-to-phase short circuit and if one occurs the reactors intervene to limit the current.

Experience indicates that in addition to a proper scheme of connections for reactors, the following points among others should be given careful consideration:

Terminals should be placed at opposite ends of a reactor to prevent danger from flashover across terminals and with the vertical-phase separation one terminal can be placed at the top and one at the bottom of the coil.

Non-combustible material should be used in their construction.

Reactors should be satisfactorily insulated from ground and enclosed in a compartment arranged for ventilation.

Reasonable clearances should be provided to all magnetic material.

Insulation of conductors, if used, should be of heat-resisting material.

As the reactor is installed as a protective feature, it should be carefully constructed and installed in every detail so that the chances of the reactor, or its connections, being the source of

trouble or the means for spreading trouble will be reduced to an absolute minimum.

Mention is made in this paper that when one or more generators are disconnected from the bus, adjacent sets of reactors are automatically shunted by short-circuiting breakers, thereby preventing more than one set of bus reactors being connected between two adjacent running generators. A description of the means for automatic shunting of the reactors would be of interest.

S. I. Oesterreicher: In this paper there is one set of records of particular interest to me, namely, the short-circuit disturbances in the West End Power Station of the Union Gas & Electric Company of Cincinnati.

It is stated in the paper that in one case the magnetic attraction between two adjacent co-axially arranged reactors was of sufficient magnitude to damage the two reactor housings. With a separation of 12 in. between the two concrete housings, the magnetic centers of the two coils are 33 in. apart. At this distance and with 6000 amperes flowing across each reactor the magnetic attractive forces between the reactors was about 14,500 lb. The weight of the reactor was only 13 per cent of the attractive forces. Thus the damage done to the concrete housings due to their tender contact is excusable, if it is known that no interbracings between the two reactors were used.

The other set of records about which I desire to comment refer to the eight disturbances of the North East Power Station of the Kansas City Power & Light Company. Of these eight disturbances, six were caused by lightning troubles. The paper states that: "In the majority of those cases the damage consisted of the breakdown of one or more current transformers followed by an arc which burned one or more feeder reactors, etc." I believe it to be unfair to record in this paper reactor failures caused by lightning disturbances.

In my humble opinion, a current-limiting reactor will give no protection against lightning regardless of its type of construction. It would be of interest to know whether or not these reactors had shunted resistors. This would throw light to some extent upon a very live topic among many engineers.

A. M. Rossman: We are indebted to Mr. Eales for the information he has given us on the recent short circuit in the Cahokia Switch House, and the protective measures he has decided to install to limit the extent of the damage in the event of another short circuit. I believe the ground relaying system which he describes to be a step in the right direction.

Mr. Stone emphasizes the fact that in the two cases which are cited, where the bus bars were directly involved in a short circuit, the power station was completely shut down. Our paper states that in each of these instances the bus bars were cleared, as a safety measure, by the switchboard operators themselves, before they could definitely determine the exact location of the short circuit. Had they opened the bus-section oil circuit breakers instead of the generator breakers, or had there been a relaying system similar to the one described by Mr. Eales, I doubt if there would have been any interruption to service outside of the bus section which was actually involved in the arc.

Mr. Kierstead, Mr. Oesterreicher, and others lay stress on the need for reliability of the reactors themselves. I might say that of all the cases of trouble given, not one originated in the reactor itself, nor did any of the reactors develop weaknesses under short-circuit conditions. Several of the Kansas City feeder reactors were damaged by arcs which started in current transformers when lightning came in over the overhead 13.2-kv. feeder circuits and broke them down. This source of trouble has since been eliminated by placing all of the outgoing 13.2-kv. feeders under ground and by relocating the current transformers.

Mr. Summerhayes has discussed the effect of bus-bar reactors on the voltage of the different bus-bar sections. We have found that with the reactors we have used, the ratings of which were carefully determined by considering both voltage regulation under normal conditions and current flow under abnormal conditions, this has given us very little concern. With a radial system of feeders, which is the system followed in the three power stations under discussion, this effect is negligible.

Mr. Osgood has asked how the bus-bar reactors are automatically shunted in and out of service. This we have done by providing either an auxiliary contact on the control switch of the main generator oil circuit breaker, or an auxiliary switch on the generator oil circuit breaker itself. When the operator closes the generator circuit breaker, the circuit breaker shunting the corresponding bus-bar reactor opens; when he opens the generator circuit breaker, the breaker shunting the bus-bar reactor closes.

In concluding, I might state that our experience with power-station reactors has fully justified our expectations and has strengthened our confidence in them as a means of successfully keeping within controllable limits, the flow of current during short circuits.

A TWO-SPEED SALIENT-POLE SYNCHRONOUS MOTOR[1]

(WIESEMAN)

ST. LOUIS, MO., APRIL 14, 1925

S. H. Mortensen: Mr. Wieseman's paper brings out, clearly, the fact that two-speed synchronous motors can be built economically, and that a machine of this kind properly proportioned will practically maintain all the virtues of the standard salient-pole synchronous motor. The field of application for a motor of this kind is at the present time rather limited. The only application the speaker can think of in addition to the ones Mr. Wieseman has mentioned is that for driving two-speed pumps such as are sometimes used with condenser installations.

This type of drive would, of course, not be a constant-torque proposition at the two speeds any more than the mine fans mentioned by Mr. Wieseman. The horse power required at either of these drives varies approximately with the cube of the speed of operation. A study of the starting characteristics shown in Figs. 21 and 22 indicates that with 12-pole stator connections, this machine can start and synchronize more than full load. With 24-pole connections, its starting characteristics are much inferior. However, very large loads corresponding to the 24-pole operation could be brought into synchronism by starting the motor as a 12-pole machine, bring it up to a speed beyond the 24-pole synchronous speed and then by suitable switching, change its stator connections from a 12-pole to a 24-pole winding. The fields could then be excited and the motor would slow down and lock into synchronism. If this procedure is followed for fans, pumps and similar drives, the motor could be started upon a comparatively low starting voltage and brought into synchronism without causing undue line disturbances.

In connection with the starting-torque curves, Figs. 21 and 22, it would be of interest to know if these curves were obtained with the motor fields short-circuited on themselves, or through a resistance, or, possibly, with the field circuit open at the starting period.

The efficiencies shown in Fig. 23 are at full load from 1 per cent to 1½ per cent lower than the efficiencies that might be expected upon a single-speed machine of this rating. At fractional loads, this condition will be even more favorable to the standard machine. In this connection it would be of interest to know what class of steel is used in the stator of this particular machine. The flux-distribution curves shown suggest that high-silicon steel would have a decided advantage over standard steel to the extent of reducing eddy-current and hysteresis losses. As the flux waves shown in Figs. 16 and 17 have very decided ripples, it would be of interest to know whether this machine was noisy during operation.

Regarding Mr. Wieseman's statement that a machine of this design is only slightly more expensive than a standard machine, it would seem to the speaker that this would apply only to

1. A. I. E. E. JOURNAL, April, Vol. XLIV, p. 339.

high-speed machines, where the field leakage and heating of the rotor coils is not a limiting feature. Where slow-speed machines are involved, the increased field leakage, in addition to the reduced field ventilation caused by the proximity of the pole tips, would limit the output and make it necessary to supply a considerably larger machine for two-speed operation than would be necessary for a standard one-speed machine.

H. Weichsel: We have been accustomed for many years to hear and talk about multiple-speed induction motors, and, on the other hand, we had a more or less deep-rooted belief that synchronous motors are inherently single-speed machines. This limitation has been taken more or less as a matter of course without analyzing the underlying reasons why synchronous motors were not built as multiple-speed machines.

During the last few years, the general interest in the synchronous motor has grown enormously. This is largely due to the better understanding of the tremendous losses and engineering difficulties which are created in a-c. systems when energy is transmitted under low power factor. The operating difficulties and economic losses, due to low power factor, hit the operating engineer first, then the consumer, and, finally, reacted upon the manufacturer of the electric machinery.

We are now in the third stage, as is evidenced by the fact that a very large number of operating engineers and power consumers have turned for help to the motor manufacturers, asking them to assist in solving the tremendously important question of power factor correction. The result of this appeal has been that during the last few years, great efforts have been made to introduce more generally the application of such motors as inherently operate at unity or even leading power factor. It is a well-known fact that the synchronous motor has the desired property of operating with leading or unity power factor. Unfortunately, while the conventional type of synchronous motor possesses the desirable ability of good power factor, yet it is also guilty of several serious shortcomings in comparison with the induction motor so generally used at present.

The designing engineers, as well as the inventors, have worked diligently during the last few years on the problem of freeing the conventional synchronous motor of its shortcomings. It is well-known that during the last few years remarkable progress has been made in approaching the goal of an ideal single-speed synchronous motor, but thereby still leaving the field of multiple-speed motors to the induction machines. This, on the other hand, is particularly undesirable from the power factor viewpoint, as all induction motors, and especially multiple-speed induction motors, have a poor power factor at low speeds.

Mr. Wieseman is, therefore, to be congratulated for having attacked the problem of two-speed synchronous motors and solved it in a remarkably satisfactory manner.

As far as I can see, in analyzing the problems of two-speed synchronous motors, it appears that the real problem lies in the rotating or d-c. member. The regrouping of the d-c. pronounced poles, such as are used in the conventional type of synchronous motor, is extremely simple in principle when a speed ratio of 1-to-2 is desired and has been understood for many years. Unfortunately, such a regrouping of the poles of a standard synchronous motor produces an entirely unsatisfactory field distribution which results in excessive losses and low weight efficiency of the machine. The problem of producing two-speed primary windings, on the other hand, is in principle the same as that which for many years has been solved in connection with two-speed induction motors.

The important question is, therefore, the creation of a d-c. member which can be satisfactorily excited for two different numbers of poles. In order to accomplish this result, Mr. Wieseman found it necessary to reduce the distance between the pairs of poles to a value very materially below the distance between pole horns as found in standard designs. From Fig. 4 of the paper, it appears that the gap between two adjacent pole horns is made so small that the surface of those poles which form one pair approaches, in its appearance, the cylindrical surface of an induction-motor pole. The following question arose in my mind:

Why not go the whole way and construct the rotor entirely on the lines of an induction motor and provide the rotor with a winding which allows the regrouping of poles in the ratio of 2-to-1. It is well known that such an arrangement can readily be obtained, for instance, by winding the rotor exciting winding as per Fig. 1 herewith. This winding consists of two groups of poles which can be reversed against each other, similar to the arrangement shown in Fig. 6 of Mr. Wieseman's paper. Single-

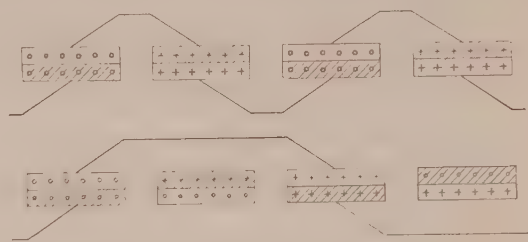


FIG. 1

speed synchronous motors without pronounced poles, using a kind of induction motor rotor, have been built very successfully for several years, especially by some European concerns. They are known under the name of "synchronous induction motors."

These motors have shown themselves in several respects superior to the conventional type with pronounced or salient poles. It is possible to obtain with this type of synchronous motor starting and synchronizing characteristics which are superior to those usually available in pronounced pole synchronous motors. This advantage is obtained by using the rotor during starting as the wound secondary of an induction motor. By introducing resistance in this winding, a high starting torque with low starting current can be obtained, and when machine has come up to speed, the induction motor slip can be held very low,

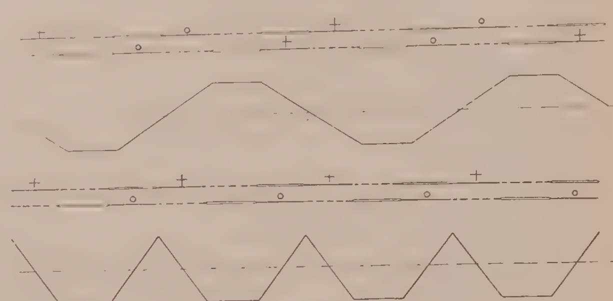


FIG. 2

as the winding is completely short-circuited. This low slip, on the other hand, results in a good synchronizing torque.

I have made some very rough calculations for a medium-size machine of moderate speed which seem to indicate that two-speed synchronous induction motors are quite feasible. I would like to ask Mr. Wieseman's opinion on the possibility of such a type of machine. No doubt, Mr. Wieseman has investigated this problem and is in a position to point out the shortcomings of a two-speed synchronous induction motor when compared with a two-speed salient-pole synchronous motor.

Mr. Wieseman makes a statement which is particularly interesting to me, namely, that the stator winding for the high-speed connection should have a coil pitch of about 50 per cent to 60 per cent which makes the coil pitch 100 per cent to 120 per cent for the low-speed connection.

This is exactly the relation which designers have found to be feasible for two-speed induction motors. In the design of induction machines, it has been found that if the coil pitch for the high-speed differs materially from 50 per cent, then the shape of the magnetic field for the slow-speed connection is very undesirable. In Fig. 2 herewith, a three-phase winding with 66 per cent for high-speed (4 poles) and 132 per cent for low-speed (8 poles) has been shown. The field for the slow speed can be considered as being made up of a symmetrical 8-pole field and superposed over this are fields with a different number of poles than desired. These higher "harmonic" fields are quite detrimental for multiple-speed induction motors and are often responsible for subsynchronous speeds and also for abnormally

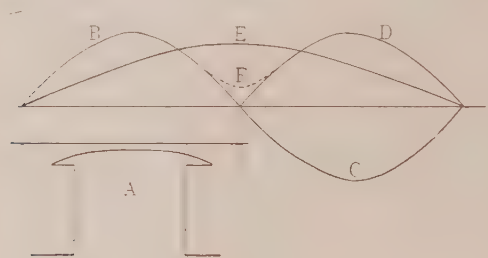


Fig. 3—Pole Shop Giving Ideal Wave Form at Half Speed

large leakage with consequent reduced output of the machine. I surmise that this is the reason why Mr. Wieseman recommends for two-speed synchronous motors, a coil pitch of 50 per cent to 60 per cent of the high-speed pole pitch.

The starting performance of the two-speed synchronous motor as given on the seventh page of Mr. Wieseman's paper is very satisfactory. It would be of interest, however, if we could hear from Mr. Wieseman regarding the synchronizing torque which these machines are capable of developing, and in this connection, he might enlighten us also on the question as to whether these machines can be switched from low-speed connection to full-speed connection, and vice versa when operating under full load. In other words, is or is it not necessary to remove the load before the windings can be switched from one speed to another?

In Figs. 16 and 17 of Mr. Wieseman's paper, oscillographic records are given of the voltage in a search coil. Mr. Wieseman then draws in Fig. 18, the "tested" field shape by using the oscillogram records for the voltage neglecting the ripples in the voltage oscillograms.

In the A. I. E. E. Proceedings 1912, page 526, I pointed out that the photographic records of the voltage induced in a search coil do not represent the true field distribution, because due to the passing of the teeth, the magnitude as well as the shape of the magnetic field produced by the d-c. winding is not constant but changes rapidly when the teeth pass each other, due to the movement of the rotor.

I presume that this phenomenon induced Mr. Wieseman to draw the tested field curve from the oscillograph record by neglecting the ripples and thereby obtaining a kind of an average.

J. F. H. Douglas and E. W. Kane (by letter): One understands upon reading the section headed "Special Pole Necessary for Two-Speed Operation," that this pole contributes to the efficiency of the motor's operation, and that the core loss is kept within 15 per cent of the value usual in single-speed motors of this size, and with a reasonable leakage. However, it does not appear that the more usual shapes of pole shoe would be inoperative, nor is it claimed that the pole shown is a form giving maximum effectiveness or that the wave form is good. Data on the maximum power factor obtainable with this motor running light would be of interest in this connection.

One understands that the poles are close together to cut down core loss, yet by referring to Figs. 16 and 17, we see pronounced ripples which must increase core loss. These ripples are of the 31st and 33rd order in Fig. 16 where the stator teeth per pole are 16. Fig. 17 has large 15th and 17th harmonics when the stator teeth per pole are 8. Both cases come under the general rule applying to tooth harmonics, namely, if N is the number of teeth per pole (being an integral number) then they may cause harmonics of the $(2\,N \pm 1)$ order. They may be eliminated, of course, by partly closing the slots, but they can be also eliminated by eliminating harmonics of tooth-ripple frequency from the pole shoe. The proof of this proposition was given in an appendix to a paper we read in Chicago June 1924 before A. I. E. E. on "Potential Gradient and Flux Density."[2] At any rate, a Fourier analysis of curves in Fig. 18 was made, and even without pronounced ripples of flux showing, harmonics of considerable size of the above orders were found.

An ideal wave form for low speed is shown in Fig. 3 herewith by curve B C from poles A. When the poles are reversed for high-speed operation the curve B D would probably result with the cusp replaced by F. The core loss of this wave would probably be 50 per cent greater than a sine wave, but the flux lost would not be the area between the two peaks B and D but merely the difference between the peak B and the peak of E the fundamental sine-wave component. The T. I. F. of the wave was computed as 235, and while interference is of no particular interest in this connection, this factor will serve as well as any for relative comparisons.

An ideal wave form for the high speed is shown in Fig. 4 herewith by the curve B C produced by the split pole A. When the pole halves are properly reversed for half speed, the wave B D E results, which has a T. I. F. of 1040, worse than the first wave in Fig. 3. With the pole tips separated to point F, we have the arrangement devised by Mr. Weiseman, with rounded corners H for the low speed, and the dip or dimple G for the high speed. We analyzed the wave forms shown in Mr. Weiseman's paper in Fig. 18, and found that for the low speed the T. I. F. was 140, and for the high speed the T. I. F. was 286.

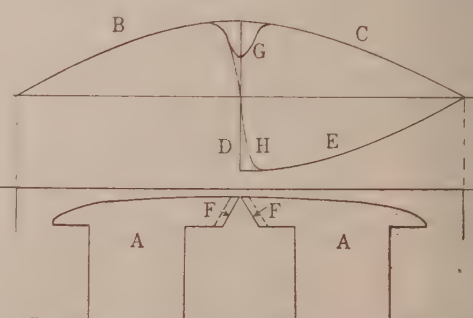


Fig. 4—Pole Shoe Giving Ideal Wave Form at High Speed

It is plain then that a perfect wave cannot be found for both speeds, but that a compromise must be made. If it were thought desirable, we have no doubt further improvements could be made. How well this design secures a favorable compromise on all of the questions involved in the design is truly remarkable.

R. W. Wieseman: The twelve-pole starting characteristics, Fig. 21, are much better than the twenty-four-pole characteristics, Fig. 22, as Mr. Mortensen has pointed out. This was mentioned in the paper and the reasons for this difference were given. In a three-phase motor the difference between the two starting characteristics would not be so pronounced because in a three-phase machine the air-gap flux density can be more readily made the same for both the high- and the low-speed conditions. The

2. A. I. E. E. Journal, December 1924, p. 1143.

starting characteristics, Figs. 21 and 22, were taken with the field winding open-circuited. If the field winding had been short-circuited through a suitable resistance, the starting torque (at zero speed) would have been a little lower, but the pull-in torque (at 95 per cent speed) would have been considerably higher.

Mr. Mortensen stated that the full-load efficiencies are from 1 to 1.5 per cent lower than the efficiencies that might be expected from a single-speed machine of the same rating. Whether an efficiency is high or low is a matter of opinion. The efficiency of a machine depends largely upon the amount and kind of material which is used in its construction. With a better grade of iron and additional copper, there is no question that the efficiency of the motor could be increased. This increased efficiency, however, would increase the cost of the motor and, consequently, it depends upon how much a per cent of efficiency can be capitalized. A machine which is used continuously should naturally have a higher efficiency and cost more than a machine which is used periodically.

Mr. Mortensen also stated that since the flux waves, Figs. 16 and 17, have very decided ripples, it would be of interest to know whether this machine is noisy during operation. At the low speed the motor is very quiet, having no magnetic noise and only a little windage noise. At the high-speed there is no magnetic noise, but the windage noise is much more pronounced.

Mr. Mortensen has called attention to the fact that a low-speed motor of this type would be considerably larger than a standard single-speed motor. I agree that a low-speed machine of this type is larger, and, therefore, more expensive than the standard motor. However, this motor is in reality two synchronous motors in one so that it is natural that the motor should cost more than one standard motor. Just how much more a two-speed motor would cost depends somewhat upon the speed.

The cylindrical rotor with a distributed rotor field winding could be used successfully in a two-speed synchronous motor as described by Mr. Weichsel. This construction would be advantageous only for small machines; for large motors I think the salient-pole and concentrated-field winding would be more economical and more efficient.

The choice of armature coil pitch for a two-speed synchronous motor is determined by the same principles as the case of the two-speed induction motor as Mr. Weichsel has pointed out.

The possibility of changing from low to high speed when operating under full load depends upon the design of the pole-face starting winding and the moment of inertia of the load. Synchronous motors can be built with very heavy starting windings (with a large thermal capacity) which can furnish full-load torque for an appreciable time. This type of machine is naturally more expensive than the ordinary motor. Furthermore, a large pole-face winding requires a deep pole tip which reduces the available space for the rotor field coil and it also increases the field leakage flux. Consequently, a synchronous motor (single-speed or multi-speed) which is designed to accelerate normal torques is not so good a synchronous motor as one which has the usual starting winding. The motor described in this paper is capable of giving full-load torque from 50 to 90 per cent speed. At the high-speed connection with 65 per cent armature voltage. By short-circuiting the field winding with a suitable resistance, and then exciting the field winding, the motor should pull into synchronism. If the inertia of the load is such that this operation could be accomplished in less than a minute the motor would not overheat. In changing from the high speed to the low speed under load, the problem is not so difficult. With a little practise, I think an operator could synchronize the motor as it comes down through half-speed with a reduced voltage impressed on the armature winding.

The voltage wave induced in an exploring coil is not strictly the same as the flux wave as pointed out by Mr. Weichsel. My reason for omitting the ripples in the flux waves, Fig. 18, was to check the predetermined flux waves. The usual design calculations will not give very accurate results when they are applied to a machine which has a special field structure as shown in Fig. 15. Therefore, it was necessary to predetermine the flux distribution over the poles and then obtain the various flux-distribution coefficients which are used in the design calculations. In predetermining the flux distribution in the air gap graphically by plotting the equipotential lines of magnetomotive force and the tubes of magnetic flux, it is convenient to neglect the influence of the stator slots and the rotor pole-face winding bars. It is assumed that the flux waves obtained in this manner will be average waves and that the distribution coefficients obtained from these flux waves will, therefore, represent the average condition. In this way the characteristics of the motor, Figs. 19 and 20, were predicted very closely.

Messrs. Douglas and Kane stated that it did not appear that the more usual shapes of pole shoe would be inoperative. Of course not, and the paper contains no statement to the contrary. However, the usual pole shape would not be so efficient as the one shown in Figs. 4 and 5. The maximum power factor obtainable when this motor is running light at either speed is 100 per cent.

I am at a loss to know why Messrs. Douglas and Kane calculated the telephone interference factor (T. I. F.) of the flux waves and not the voltage waves. The T. I. F. factor is the number of micro-amperes per volt flowing in a tuned network which is weighted so that the current will be a maximum at 1120 cycles. Since the flux wave cannot appear at the terminals of the motor, it can not affect a telephone circuit, so that the T. I. F. of the flux wave is useless. Furthermore, the T. I. F. reading favors the seventeenth and the nineteenth harmonic in a 60-cycle wave while other harmonics have a reduced effect. Consequently the T. I. F. is only an indication of the relative value of a few harmonics in the wave and not a measure of all of the harmonics. The discussion of the pole shape by Messrs. Douglas and Kane, as shown in their Figs. 3 and 4, is practically the same as that given in the paper.

COMMUNICATION IN RAILROAD OPERATION[1]

(Forshee)

St. Louis, Mo., April 15, 1925

V. E. Thelin: One of my duties with the street railway system in Chicago is that of telephone engineer. I find that there is a particular class of work in our company in which we are at a great disadvantage; namely, that of keeping in touch with the line-construction trucks, wrecking trucks, as we use the term *i. e.*, trucks that go out and take care of accidents on the road and with our emergency trucks that repair trolley breaks, etc. I was wondering if it is possible to use the d-c. feeder network as a conductor for carrier-wave transmission as is now being done by power distribution companies on their high-voltage transmission lines. This d-c. feeder network totals approximately 1000 mi. of single track and loops into some thirty-three substations, which possibly complicates matters.

C. H. Gaffeney: The Central Railroad Company of New Jersey was among the first to adopt the loud speaker for individual train dispatchers' use to take the place of the telephone headset. In fact, the first model approved at the Western Electric Company's laboratory was placed on one of our circuits in the Jersey City Terminal train-dispatcher's office. After a fair try-out, it proved far superior to the old system in efficiency and as a time saver, as well as for the comfort of the train dispatcher, by eliminating the sore ear and the fear of working in electrical storms. It enabled the superiors to hear and direct train operations without removal of the headset by the dispatcher as under the old system.

W. Rogers: I would like to point out that the railroads of the United States are, perhaps, the second or third largest wire-using

1. A. I. E. E. Journal, May, Vol. XLIV, p. 451.

organization. They are handicapped, however, by reason of the fact that this enormous wire mileage is not operated as a unit. It is divided into systems, perhaps from two or three hundred miles long to systems of many thousand miles, like Mr. Forshee's system. The result of that has been a lack of coordination of engineering effort until very recently, and there is still a great deal to be done in that respect.

Mr. Forshee stated that our problems are very similar to the problems of the commercial telephone companies, with some special exceptions. That is true, but we have not been able to attack them as the American Telephone & Telegraph Company has attacked its problems; nor have we been able to handle our telegraph problems in the way that the large telegraph companies handle theirs. In fact, the situation has been that the telephone and telegraph engineers on the railroads have directed their efforts towards adapting for railroad service the commercial developments of the telephone and telegraph companies.

I hesitate to say anything that might indicate that I am opposed to improvement and progress, but I do not think the record should be allowed to stand, that in its present state of development the loud speaker for telephone train dispatching is entirely satisfactory. I believe that it will be, but I hope that the people who are working on that development do not feel too self-satisfied and stop where they are.

Mr. Gaffeney pointed out that it has certain advantages. It has one inherent disadvantage,—it permits the train dispatcher's attention to be distracted. The fortunate fact in regard to the use of the head receiver is that when the dispatcher has the head receiver on it is very difficult to distract his attention, but when he uses a loud speaker he is unable to concentrate on his work to the same extent. So I hope that the communication engineers who are developing loud speakers will not think that the present loud-speaker development for train dispatching is complete.

In regard to this same subject, it seems to me that we did not do enough for the dispatcher in the way of developing his present head receiver. If we could get a head receiver that would be comfortable, or substitute something for the head receiver that would retain the inherent advantage of keeping the dispatcher's attention concentrated on communication on the telephone, rather than what goes on in the room, that would be a step forward. A compromise between the present head receiver and the loud speaker may be the solution.

C. E. Stryker: On account of the magnitude of the subject, Mr. Forshee's paper was necessarily limited to a summary and some of the very interesting features of railroad communication were not very thoroughly treated. One phase of the subject was entirely omitted; namely, the power supply required for various communication circuits and devices. The earliest simple telegraph circuits received their energy from gravity batteries, and, with the development of new types of circuits and also of other sources of power, the gravity battery has been replaced by the soda type of primary batteries, dry batteries, motor-generator sets, storage batteries and finally rectifiers, particularly those of the tantalum electrolytic type.

Requirements of communication circuits are very diverse, ranging from several milliamperes at a very low voltage for local sounder circuits to ½ ampere or more at 500 volts or higher for the operation of telephone selectors. In some cases batteries are required to insure continuity of operation. This would be the case with principal circuits where even momentary interruptions could not be tolerated. For other applications it is possible to make use of a power supply without batteries because the relatively small possibility of the power being off does not seriously interfere with the operation of the circuit. Cases of this kind are the operation of telephone selectors and various loud-speaking outfits.

The present trend is very decidedly toward the elimination of maintenance as far as possible and toward the use of generated power which can be obtained almost universally at a cost which is only a small fraction of the cost of power produced by chemical action as in primary batteries. This tendency makes the use of such devices as rectifiers which are without moving parts desirable and has resulted in remarkable savings in cost of operation and in increased reliability of service.

I. C. Forshee: Mr. Thelin raised the question about a means of communication with his trouble wagon. It would seem that there might be a solution, using either the radio or a carrier system. The Westinghouse, General Electric and the Western Electric have developed carrier systems that might be adapted to that service.

Mr. Gaffeney raised the question about the type of loud speaker used on the Pennsylvania Railroad. There has not been any standardization of any particular type of loud speaker, although they have been generally used on our dispatching systems.

Mr. Rogers suggested a further development of the head receiver as it might work out more satisfactorily than the loud speaker and might possibly obviate some of the difficulties of the latter. The principal suggestion was that it be made more comfortable for the dispatcher. There are other features, as I see it, which are necessary to produce comfort for the dispatcher under all operating conditions which the head receiver cannot possess.

There is one condition around the railroads that they do not have control of; that is, the presence of power circuits. There are many places where power lines parallel the railroads, and those power circuits do not always operate perfectly. In other words, there are short circuits and grounds that affect the adjacent communication system. It is necessary to overcome that trouble, if one is to wear the head receiver with any degree of safety and comfort. One means is the limitation of short-circuit or ground current in the power system; another is the development of more efficient protectors for our communication circuits; and a third is the use of acoustic shock reducers which is a new development in the field. Lightning discharges also cause unpleasant sensations in the head receiver. The loud speaker overcomes many of these troubles.

The lightning arrester for the communication system is something that has been given very careful consideration for years and they do not have the answer yet for perfect protection.

The further development of the head receiver, I believe, should be given consideration as there are certain combinations of windings that have a decided effect upon results obtained.

ECHO SUPPRESSORS FOR LONG TELEPHONE CIRCUITS[1]

(Clark and Mathes)

St. Louis, Mo., April 15, 1925

S. P. Shackelton: When any device, which differs as fundamentally from the existing order of things as the echo suppressor is introduced into a working system there will arise problems as to its practical application. To a very large extent these problems have been met in the installation at Harrisburg which is referred to in the paper. It may be profitable to review somewhat the experience obtained in that installation.

It will be realized that the proper association of an echo suppressor with a telephone circuit is essential for satisfactory operation. This involves not merely obtaining the correct circuit connections in the office where the suppressor is located but also in securing a suitable circuit layout for the entire length of the telephone circuit. While considerable latitude is possible in the geographical location of the suppressor, still the time intervals introduced by the relays require that it be located at some distance from the ends of the circuit. The introduction of telephone repeaters a number of years ago imposed somewhat similar restrictions as to circuit-layout

1. A. I. E. E. Journal, June, Vol. XLIV, p. 618.

changes. These factors all tend to eliminate temporary circuit-layout changes and to confine the changes to those authorized after consideration of complete circuit requirements. This is particularly true on toll cable where the need for emergency changes is less frequent than with open-wire lines.

A consideration of the operating conditions to which echo suppressors are subjected suggests certain differences between the relay requirements and those usually met by telephone relays. As a rule relays are given specified adjustments, either mechanical or electrical or both, and then are expected to function in the circuit with a certain margin between the adjusted condition and the normal working condition. In the echo suppressor no such margin is possible, the relay simply operating on voice currents of sufficient magnitude and failing to operate on weaker ones. The margin here required is not possible in the usual sense by means of relay adjustment and hence the provision is made for varying the sensitivity by means of different connections to the input transformer. It will probably not be possible to adjust all circuits for the same sensitivity owing to the different conditions of noise and energy level encountered. Also the margins may differ widely. In fact, there may be no margin in the usual sense, the suppressor being adjusted to operate only on the relatively strong voice currents.

No unusual maintenance requirements are introduced by the use of echo suppressors in the plant. The conditions just outlined call for somewhat different treatment, however, than is usually followed. The paper outlines the operation of a testing circuit for checking the relay adjustment. Such a circuit indicates the combined effect of all the time intervals introduced by the different relays in normal operation modified by the action of the amplifier rectifier in short circuiting its input. Even with the use of such a testing circuit it is necessary to give the individual relays their proper adjustments. Also some experience is necessary in the use of the testing circuit to interpret its results. Provision is made for reading the current in relay *A* Fig. 3, in normal operation and at the same time it is possible to monitor on the suppressor. In this way a check on the operation can be obtained. This is particularly desirable as the relay *A* is subject to severe operating conditions and requires closer maintenance than would be the case for direct-current operation. It is to be noted that the entire operation of the circuit is dependant on relay *A*.

In usual telephone practise, even with the simplest circuits, whenever relays are involved, it is customary before putting a circuit in operation to check the relay adjustment by means of a current flow and give the prescribed current-flow adjustment for those relays. An interesting incident in connection with the installation at Harrisburg, might be brought out. The suppressors were all assembled completely in the Western Electric Company laboratory, tested out and shipped to Harrisburg. In shipment, relays cannot be expected to maintain their adjustment. The men who put the suppressors into service at Harrisburg had had no previous instructions as to relay adjustments, and yet in spite of that fact when they completed the installation, they put one of the suppressors on a telephone circuit which was set up for trial without any check whatsoever on the adjustment, and it worked along very nicely. This would bear out our assumption that in spite of the fact that maintenance conditions may be somewhat different, they are not any more severe than any normal circuit operation.

H. S. Foland: In connection with echo suppressors for long telephone circuits, it occurs to me that some additional discussion of the trial installation at Harrisburg may be of interest.

The paper mentions this installation and shows a picture of the apparatus as installed. Harrisburg was selected as a suitable location for a trial installation of this apparatus for several reasons:

First: There were four-wire cable circuits between New York and Pittsburgh, so loaded that any material extension of them should result in noticeable echo effects. These circuits were of course, provided primarily for New York-Pittsburgh circuits.

Second: It was possible to extend these circuits from Pittsburgh by means of several different types of facilities to points sufficiently distant to produce the desired echo effects.

Third: Harrisburg is suitably located between New York and Pittsburgh to provide the time interval required for the apparatus to function and to permit the operation of the circuits to be observed from the New York end.

Fourth: Harrisburg is a repeater point on these cable circuits, (approximately at the center of the New York-Pittsburgh section) and thus a suitable point for an echo-suppressor installation.

Ten 19-gage, medium heavy loaded four-wire cable circuits between New York and Pittsburgh were taken and the Pittsburgh terminals extended to a number of distant points over a variety of types of facilities:

Four circuits were extended to Chicago by means of four-carrier telephone channels;

One circuit was extended to Chicago by means of an open- wire circuit:

One circuit was extended to Cincinnati by means of an open-wire circuit;

Three circuits were extended to Cleveland by means of cable facilities between Pittsburgh and Cleveland, in part four-wire and in part two-wire;

One circuit was extended to Detroit by means of an open-wire circuit to a point near Toledo and from that point to Detroit in a two-wire cable circuit in the Toledo-Detroit Cable.

It will be appreciated, I believe, that this was a rather comprehensive selection of facilities on which to institute a trial and that the results obtained from these several combinations might reasonably be taken as indicative of the performance of the echo suppressors.

These circuits were then equipped with the echo suppressors at Harrisburg and a close supervision maintained of their performance, both from the standpoint of equipment trouble and from the standpoint of the effects of the echo suppressors on the operation of the circuits. The data collected have indicated that these echo suppressors function in an effective manner and that they have not been subject to an abnormal amount of trouble.

The paper points out that this apparatus operates so as to short circuit the return transmission path. This was an interesting feature from an operating standpoint, since the thought naturally occurs that such an arrangement would give the speaker right of way over the circuit and that the listener at the opposite end of the circuit would be compelled to wait until the speaker had finished or at least had made an appreciable pause before it would be possible to interrupt him. A very considerable number of conversations were carefully observed to determine if there was any indication of this effect, and it was established that the users of these circuits carried on conversations in a perfectly normal manner, interrupting one another in apparently the same manner as on circuits not so equipped. This result may be explained, of course, by the very short intervals of time involved in the operation of this equipment.

From an operating and maintenance standpoint, there was something disturbing in the thought of giving service dependent upon the operation of relay equipment a considerable distance from the speaker and actuated by the speaker's voice, but experience with the Harrisburg installation has indicated that the echo suppressor is a practical device, both effective and reliable in its operation.

A. B. Clark: I do not want to leave the impression that echo suppressors are vitally needed on all cable circuits. As a matter of fact, there are in service today types of cable circuit capable of giving a good grade of commercial telephone transmission for

distances of at least 1000 mi. without any echo suppressors at all. However, it is possible that in certain cases echo suppressors may allow the desired transmission results to be secured more cheaply.

The echo suppressors which have been installed at Harrisburg and have already been referred to are working on types of cable circuit which were designed for use up to moderate distances only. When the echo suppressors were placed on these circuits, the circuits were intentionally pushed beyond the limits for which they were originally designed. If the "long-distance type of cable circuit" were available, it would be possible, for the circuit lengths involved in this case, to dispense with the echo suppressors at Harrisburg.

APPLICATION OF MOTORS TO MINE LOCOMOTIVES[1]

(W. A. Clark)

St. Louis, Mo., April 17, 1925

C. Lee: The last paragraph of Mr. Clark's interesting paper brings out a point that has not been considered of much weight in the past, but which has recently been taken into account in some installations of gathering locomotives. It should be considered in all cases.

The duty cycle of a gathering locomotive and the physical condition of tracks, curves, etc., on which it operates certainly make it impractical to take advantage of the full-speed characteristics of a 7-mi. per hr. gathering locomotive. Locomotives built and rated at such speed have been sold to mine operators, because the operators have asked for a standard locomotive. The manufacturer offers a 7-mi. per hr. locomotive as a standard. In some cases the operator wants a locomotive that can be used interchangeably for gathering or hauling service. A locomotive built to meet such requirements is not the most practical.

Therefore, it seems that the manufacturers should build, rate and sell gathering locomotives rated at a speed of 3½ to 5 mi. per hour, as *standard* gathering locomotives.

E. J. Gealy: As an added bit of information necessary to apply a mine locomotive successfully to a given service, I might suggest that the size rail be considered. Most mining companies use smaller rails than advisable from a tractive point of view. To put a relatively heavy locomotive on a small rail is uncommon. Under such a condition the top of the rail is so narrow that a new set of locomotive wheels rides on a line contact for a considerable period before wearing down to the shape of the rail. Thus it is impossible for the locomotive to develop its full drawbar pull.

Another important detail about a mine locomotive is the clearance of the motor casings above the rails. At cross-overs and especially on uneven track, locomotive motors often drag and produce a heavy load. In service, wheels with false flanges and under-size wheels reduce the original clearance. The common practise of using undersized wheels from one type of locomotive on another type must be carried on with consideration. Excess loads may be placed on the motors by oversize wheels and the clearance under the locomotive be greatly reduced when undersize wheels are used.

Ever since the first trolley locomotive was built the motor horse power per ton of locomotive weight has been increased. The ultimate limit for the ordinary haulage locomotive with the usual type controller, wheels and speeds, seems to have been reached. This ratio, about 12 h.p. per ton, appears to be nearly the limit because a locomotive so equipped will slip its wheels before it can be seriously overloaded. However, with the increased use of dynamic-braking controllers, which place the motors in service both when hauling and braking, still larger motor ratios per ton of locomotive weight may be required.

The ability of a slow-speed storage-battery locomotive to gather as much coal as a high-speed trolley locomotive, is significant. In gathering service, high speeds can rarely be attained consequently much energy is used up in the control resistance to keep the locomotive running slowly. When we consider the reduced speed for which storage-battery locomotives are designed, we see a very good reason for their low h. p. per ton.

W. A. Clark: Mr. Lee feels that the manufacturers should sell as standard, gathering locomotives with rated speeds of 3½ to 5 mi. per hour. A motor which will fit in a definite space will have a horse-power rating varying almost directly with the speed of the motor. The horse power of the motor on low-speed locomotive would, therefore, be low. As shown in my paper the horse power of the motor need not be high but the general demand from mines is for large horse power irrespective of the speed. When the demand for slow-speed gathering locomotives becomes great enough, they will become standard.

1. A. I. E. E. Journal, April, Vol. XLIV, p. 347.

A VIBRATION RECORDER FOR PATHOLOGICAL ANALYSES

(Hall)

St. Louis, Mo., April 17, 1925

L. W. W. Morrow: It occurred to me that it might be possible to use the vibration recorder to study vibration effects in large machines used in engineering work.

J. H. Hunt: We have tremors and vibrations to consider in the automotive industry and a device such as he has developed will be exceedingly useful for certain types of applications because the part of the instrument applied to the mechanism is so light, and, therefore, does not affect the vibration of the parts being studied. For a great deal of our work, however, we use equipment which should be useful in other branches of electrical engineering where it will not be necessary to go to such delicate devices as Mr. Hall has described. Whenever an oscillograph is available (and it seems to me that eventually all manufacturers of machinery will find oscillographs necessary) it is possible to use devices for measuring vibrations or shock which can be connected to the oscillograph and obtain these vibration records without new and expensive pieces of equipment. That is, the new part which must be developed for a particular problem would be very limited. I would suggest that persons having such problems investigate what has been done at the Bureau of Standards with the telemeter and with similar equipment and some of the work which has recently been published describing the application of the oscillograph of the study of mechanical vibrations.

C. I. Hall: I do show in one of the cuts in the paper, the tremor of a fractional-horsepower motor being started up, running in normal condition, and after the current was cut off. The film was obtained by attaching a secondary light source to the frame of the motor, arranging it in proper relation to the vibration recorder, and then closing and opening the motor circuit. In that particular case we were able to determine the amplitude and frequency of the vibrations, the direction in which it was most effective, and whether or not the motor under test was a good or bad motor for washing-machine application.

The vibration of transformer coils has also been recorded. Under extremely heavy load conditions it has been determined that the coils actually move back and forth at a rate varying with the frequency and it follows, therefore, that some transformer failures may be due simply to the scratching off of the insulation on the relatively rough edges of the laminations.

Further, mirrors of this character have been attached to rotating parts of electrical and mechanical machinery, thus obtaining graphs of vibration under conditions which I think would be prohibitive by any other method. For instance, in one of Mr. Hunt's problems on automotive devices, it would be possible to attach a secondary light source to the connecting rod of an automobile engine and in addition to its normal cycle, record all of the secondary vibrations to which it may be subject.

These little mirrors are practically without inertia as compared with the inertia of most devices to which they may be connected.

The ones exhibited are, of course, rather delicate because we have been concerned largely with recording very small amounts of motion. The smaller the amplitude of motion, the smaller must be the light source. It has been possible to obtain lines on the recording film approximately 1 mil in width. The mirrors, of course, are highly polished and after the preliminary grinding operation, require from 18 to 20 hours of polishing by a specially designed automatic machine. The polishing process is continued until a microscopic examination at 100 diameters discloses no imperfections.

Mirrors have been constructed of various materials and of various diameters. The smallest one produced so far has a radius of approximately 8 mils; the largest one 40 mils. The materials utilized have been tungsten, stellite, and hardened steel. The smaller diameter units are utilized where tremors of small amplitude are to be recorded; the larger sizes with larger tremors or where very high speed of motion makes it necessary to obtain more light.

ELECTRICALLY-HEATED LEAD, SOLDER AND BABBITT POTS

(Woodson)

St. Louis, Mo., April 17, 1925

G. R. Gosrean: A three-cornered compromise between the electrical engineer, the metallurgical engineer and the power companies has made the electric heating industry as successful as it is today, and will make it more successful in the time to come.

I was very much interested in what the author said about those large lead pots, and should be very glad if he would tell me if they have any developments in melting pots for four and five tons of lead.

J. C. Woodson: These ordinarily operate at about 850 deg. fahr. Melting pots have been made for seven and eight thousand pounds. Heat-treating pots have been made to hold approximately 4000 lb. of lead, and they operate up to 1600 deg. fahr. in the lead. This lead is covered with charcoal. The inside dimensions of these particular vessels are about 6 ft. long by 12 in. wide and 15 in. deep. In heat-treating axe blades, for instance, the blades are immersed below the surface of the lead on a rack and the operator takes them off, one at a time, placing a cold axe in the vacant place. When he gets back to the starting point the first axe is up to temperature. He can leave the axe in the lead longer than he could in a gas vessel, because the lead is at just the proper temperature and will not burn the metal.

In one plant where such a pot is in use there is evidence that they could pay three or four times for the electric heat what they were paying for gas and still not consider going back to gas because they have a product absolutely free from objections.

They ran a simple test which is very interesting. From every batch of steel received, they take samples and turn them over to their heat-treaters. The samples are sharpened and heat-treated and given a hardness test.

Since they have had these lead pots, they took twelve samples of steel and sharpened both ends of every piece. They hardened one end in the gas furnace and the other end in the lead pot. Of the ends hardened in the lead pots every piece passed the inspection test, but of the ends hardened in the gas furnace, only two out of twelve passed the test, which indicated that, while the steel was probably all right, it would have been rejected. They were convinced that there was much more in the way their steel was being heat-treated than in the steel itself.

The same is true of babbitt and solder pots. Our works at East Pittsburgh would not consider taking out those babbitt pots even though they were costing more than the old gas-fired pots, because the work is so uniform and it is the only way they can produce the quality of work they want. Therefore, they forget about the cost of power.

ELECTRIC LIGHTING EQUIPMENT ON AUTOMOBILES[1]

(Hunt)

St. Louis, Mo., April 17, 1925

R. N. Falge: Mr. Hunt points out that with headlamp beams which meet the I. E. S.-S. A. E. specifications at the *B* point (175 ft. ahead of the car) the vision of distant objects is interfered with by high road brightness near the car. It is true that this criticism applies to some of the equipments which meet that specification, but only because they are poorly designed. The fault is not with the intensity directed to the *B* point but rather because of the excessive intensities directed to the lower angles and striking the road near the car. Such undesirable light distribution is not at all inherent in the specifications. The better equipments follow the *S. A. E. Recommended Practice* which provides for a relatively high intensity at the *B* point and a gradual reduction in intensity at the lower angles to provide satisfactory uniformity of road illumination for distances of several hundred feet ahead of the car.

Mr. Hunt says that very satisfactory road illumination, quite sufficient for speeds up to 35 mi. per hour, can be obtained from lamps provided with 36 to 40 candle power filaments and large frosted bulbs when used in parabolic reflectors with plain cover glasses. That there are conditions under which this would be true, I quite agree, but as a general statement covering the range of road, atmospheric, driving and car-voltage conditions over which headlights must operate, there is ample evidence to disprove its adequacy. One might, to be sure, drive for a considerable time with these frosted lamps without encountering the more exacting conditions for vision and be quite oblivious of the potential hazards which the inadequate lighting entailed and of the extra eye strain and fatigue imposed. When, however, a car is equipped with two sets of headlamps, such that the driver can shift at will from the frosted-bulb distribution to the recommended beams, he very quickly arrives at an appreciation of the advantages offered by the latter. We have had much experience with such facilities and the various observers have all come to the conclusion that the light from the frosted bulbs is dangerously inadequate. There is furthermore, a large amount of data available as to the minimum illumination desired for safety under different road and driving conditions as determined by numerous observers in a car equipped so that they could vary the form of beam and the intensity at all angles while driving. These data indicate that devices are needed designed to direct to the road intensities of the order of those called for by the *S. A. E. Recommended Practice*. The determinations did not involve any unusual conditions as far as atmosphere or driving were concerned although they were made on roads with which the observer was not familiar. Memory and assurance of the absence of any special hazards could, therefore, not be counted upon to take the place of vision. The frosted bulb gives a maximum of only 3000 to 4000 candle power and this has most clearly been shown to be insufficient.

So much for the requirements of the man behind the lights. But what of the man approaching, who faces but 800 candle power with the conventional devices and 3000 to 4000 candle power with the frosted bulbs. Here again careful investigation and long experience has demonstrated that something of the order of 1000 candle power is the maximum value that one can face on the road without undue interference with vision. Even with that value there is glare; hence the advantage of the further relief afforded by the depressible beam, even on level roads. Without wishing in any way to discourage the careful study of all possibilities which may lead to better driving conditions at night, I feel it desirable to point out this tremendous gap between what has been found necessary on and above the road, and what is provided with the frosted bulb.

L. C. Porter: Mr. Hunt rather strongly advocates the use of

1. A. I. E. E. Journal, Vol. XLIV, May, p. 476.

the large frosted bulbs of 36 or 40 candle power, stating that this lamp gives very satisfactory side illumination. That is true; but I should like to call attention to the fact that the frosted bulb itself becomes the light source, or at least a partial light source, and the reason that it gives the side illumination is, because it is so far out of the focal point of the reflector. For the same reason the light is spread upward as well as to the sides, and it is spread upward at such a steep angle that lenses and other glare-reducing devices cannot control it. Headlamps using such bulbs, therefore, would be very glaring, and unquestionably exceed the glare limits set by the various state laws. A headlamp of this type reverts to the same general conclusion as the old Warner lenses, which were beautiful from the driver's point of view, as they illuminated all of the surrounding scenery,—even to the tops of the trees, but were abominable from the point of view of the approaching driver, and for that reason have been absolutely ruled off from the road.

W. D'A. Ryan (by letter): This paper is a direct and timely exposition of one of our greatest public menaces resulting in accidents and mortalities which are mounting at an alarming rate with each succeeding year. Unless something tangible is done to improve the situation the present automobile headlight laws and regulations must of necessity fall into disrepute. It must be admitted, however, that were it not for the I. E. S. specifications, which have been quite generally adopted, the situation would be much worse.

Some maintain that the majority of accidents are caused by glare, others claim that glare may be disagreeable but not particularly dangerous and that insufficient light on the road surface is the weak point. I am inclined to believe that if glare were eliminated we would find that we had sufficient illumination on the road surface at the present time when using the best units available. I am not opposed to increasing the illumination and believe it should be done if possible but this would be of little avail unless glare is eliminated. Just so long as we are allowed from 800 to 2400 candle power at the *C* point dangerous glare cannot be eliminated and we may as well realize this fact now. If the headlights are set for 800 to 2400 candle power at *C* point we will have glare but will comply with the range of 160 to 180 ft. as called for in the different states. If we cut the light down so that there is no glare at *C*, the range in most cases will be reduced to less than 100 ft. which is not sufficient for safe driving. This combination is brought about by the inherent defects in the design of a majority of the headlights in use to-day.

There is no rough and ready way of checking the I. E. S. specifications with any degree of accuracy in the existing testing stations. The rule now seems to be in a great many of them to tilt the headlights by bending the forks or otherwise until they consider that there is no glare, with the result that the maximum light strikes the road surface far short of the legal requirements for range. As Mr. Hunt points out, the lamp adjustment practised in one state does not of necessity comply with the adjustments in other states. I know of two cities within a comparatively short distance of each other which have entirely different ideas as to what is legal and what is not. You may have your lamps adjusted in one city and passed o. k. and be arrested in the other for improper adjustment. If the facts were known very few headlights, if any, in service would be found to comply strictly with the legal specifications on all points, and as matters now stand it is difficult to offer any useful constructive suggestions for a radical improvement before something tangible is available in the way of improved automobile headlights, other than to suggest federal control or other means of unifying the regulations in all of the states. Until this is accomplished the present absurd situation is bound to continue.

One serious objection to the use of frosted lamps, especially of high candle power, (36 or 40 as mentioned in the paper), is that the entire reflector becomes a disagreeable source of glare and as Mr. Hunt points out a great deal of this light would be reflected upwardly with sufficient intensity to give serious trouble in fog. This can be obviated with clear-bulb lamps by projecting the main beam so that the high candle power rays do not rise above the horizontal. I have found from experience that driving with such a light when you are looking over the main beam to the distant range and not through it, allows good visibility in the fog. This is further helped by direct light (not reflected) in the front and to the sides of the machine which, on account of the low candle power intensity, does not brilliantly illuminate the fog but is of sufficient intensity to make the sides of the road, edges and fences discernible.

After headlights permitting control of glare are placed on the market, high-candle power lamps to give greater road illumination may be approved, but until such time it will be difficult to convince the authorities having to do with automobile headlight regulations that a 21-candle power lamp, improperly focused, is a much greater source of glare than a 50-candle power lamp operated under proper conditions; so that for the present we are confined to the 21-candle power lamp, (which is standard for most of the states) and any improvements effected must be the result of better distribution, the utilization of stray light including that now producing glare and the elimination of losses in the housing and front door or lens. In view of the fact that there are few headlights today that are effectively utilizing more than one-third to two-thirds of the total lumens of the source, there is a fair opportunity to obtain considerably more useful light even under the 21-candle power handicap and other limitations imposed by the diversified laws of the different states.

The requirements of a first-class headlight can be summed up as follows:

First. A non-glare unit having a range between 200 and 300 ft. on a level road. It should be non-focusing, capable of operating with lamps of any candle power without change of focal adjustment.

Second. The light distribution should be of fairly wide characteristic with reasonable depth and should be homogeneous with a gradually increasing intensity from a point near the machine to the most distant point and the reflected beam should not rise above the horizontal. There is always sufficient light from even a macadam road surface to take care of softening the cut-off above the horizontal at long range. The area of greatest intensity should not be concentrated in a small spot of high candle power but should have a reasonable lateral divergence. It is important to bear in mind that a very intense spot, particularly on a wet road surface introduces a new element of glare (reflected) which should be avoided.

Third. A reasonable amount of light should be projected at right angles to the plane of the main beam and even a few degrees to the rear so as to light up the gutters and make turns safe in difficult places and also make possible the reading of road directions on either side without the use of spotlights.

Fourth. Sufficient light should be thrown on the front of the machine, that is the radiator, forward wheels and bumper, so that they are clearly visible and if one light fails there should be no chance of mistaking an automobile for a motor-cycle. The cut-off of the beam should be such that there would be no upward high-candle power rays to scatter in the fog and reduce visibility.

Fifth. There should be a general dispersion of unreflected light to illuminate trees, telegraph poles and give general vista without glare so that distance can be judged at night as in daylight driving. If the non-glare feature of the unit is further improved by lighting up the front of the machine and the general surroundings, the intensity of the source becomes less brilliant by simultaneous contrast. Furthermore, the main beam should be of such a nature that it will become even more dead as the car is

approached which in turn will improve the ability of the oncoming driver to see beyond the approaching car.

Sixth. The lights should be definitely focused for city and country driving so that there would be no necessity for dimming, tilting or other manual operations which in the majority of cases with the present increased automobile traffic is impracticable, unless operated at the low point practically all the time.

Now from a mechanical point of view:

First. The lamp should be adaptable to modification of designs to meet the aesthetic lines of the car and embody the elements of true art which at a glance suggest that the unit is primarily a functioning light source rather than a decoration.

Second. It must be sufficiently rigid in construction so that it cannot get out of adjustment.

Third. It should be dust and rainproof and a simple means of opening the door should be provided so that the replacement of lamp or cleaning of reflector can be done without the use of tools or unusual exertion.

Fourth. A simple means of adjustment of the beam should be provided which will not require bending of forks, difficult manipulations or technical knowledge; in fact, so simple that anyone can make the adjustment and there will be little excuse for failure to comply with state or police regulations.

Fifth. The headlights must be produced at a cost which will not make them prohibitive even for the low-priced cars.

I believe the above specifications are well within the range of possibility and can be made without great difficulty and at reasonable manufacturing cost.

J. H. Hunt: It seems to me that as far as the S. A. E. specifications are concerned, the greatest criticism is not against the unfavorable results that come under the special road conditions, but against the difficulty of enforcement. The regulations specify definite quantities of light flux at definite angles. The enforcing officers do not use instruments to make measurements on these requirements.

In line with what Mr. Falge has stated, it seems to me there is one defect in the specification. I wish to make the point that the maximum intensity strikes the road at 172 ft. If it strikes the road at this point, it is not available for greater distances. It would seem that an additional specification should be added to the S. A. E. specifications, limiting the light below the horizontal as well as above the horizontal.

Some comments have been made as to the speed limits of driving with cars with frosted bulbs. In the chart shown in the paper, the light along the horizontal for the frosted bulbs is about half the candle power available along the horizontal from lamps conforming to the S. A. E. specification. Now, the eye is not a physical instrument. It probably works in conformity to photochemical laws, and the relation between illumination and seeing is a logarithmic relation. As a result, the visibility of distant objects when using the frosted bulbs is very much greater than half the visibility when using lamps conforming to the specifications, particularly since there is not so much interference because of high illumination directly in front of the car. It is my personal opinion that it would be perfectly satisfactory to drive 35 mi. an hour with the frosted bulbs. This is based on considerable experience.

The only reason I am bringing these particular lamps to your attention is because they seem to offer a possibility which should be studied and they are absolutely fool-proof in their application. I will defy anybody to make an installation very much worse than the best installation can be with them.

With the windshield clean, it is perfectly possible for drivers of two cars, equipped with both of these lamps, to drive past each other on the road without dimming, and maintain 35 mi. an hour, without any more risk than is involved, I believe, in driving by with a tilted lamp. It would take quite a little investigation to find out whether they will be practicable under every conceivable condition.

With respect to driving in foggy weather, I have had a limited experience with the frosted bulbs in foggy weather, and I am convinced that in a light fog, I would be just as willing to use the frosted bulbs as the S. A. E. specification lamps. I have not had an opportunity to drive in a very dense fog and it is quite possible that they will not meet that situation. I had not expected, however, very much more trouble with them than that experienced in an ordinary fog.

LOAD-BUILDING POSSIBILITIES OF INDUSTRIAL HEATING[1]

(Ipsen)

St. Louis, Mo., April 17, 1925

H. N. Shaw: The maximum temperature of electric furnaces is fixed by the limitations of the heating elements available. Above 2000 deg. fahr. metallic elements are impractical due to their loss of mechanical strength, but non-metallic elements are now available which are practical for use in industrial furnaces operating at temperatures up to 2500 deg. fahr.

During the last few months, tests have been run on forging furnaces operating at 2400 deg. fahr. in which a non-metallic element is used, and the results have proven that a forging furnace with automatic temperature control can be built so as to be as successful as the electric furnaces now used for steel treating.

This development opens up a new field for the sale of power in very large blocks to forging shops and steel mills. One large shop, for example, will require more than 20,000 kw. when all the oil furnaces are replaced by electric furnaces. Preliminary tests have shown that the electric furnace will cost less to operate and will require one less workman, due to the automatic temperature control. Besides this direct saving, the shop will be converted from a hot smoky place to a clean cool shop and thereby reduce the labor turnover.

The use of electric forging furnaces should bring about decided improvements on present-day forging practise, in a manner similar to that in which improvements in japanning practise were brought about, by the introduction of the electric japanning oven.

C. L. Ipsen: I was very much interested in Mr. Shaw's description of a new form of heating unit which he considers suitable for use in forging furnaces. A great variety of electric forging furnaces have been designed in the past which have clearly demonstrated the desirability of using electric heat for forging but none of these has proved successful on account of the high cost of maintenance.

The question has been raised concerning the power surges caused by electric furnaces. The various ovens and furnaces covered by my paper are all of the resistance type and operate at practically unity power factor. The load is of much the same nature as the incandescent-lighting load and consequently does not give rise to any power surges.

Concerning the desirability of this type of heating load to the central stations—it might be of interest to point out here that one large central-station company made a study of the relative returns from their heating load and from their lighting and power load. It was found that the lighting and power load returned a revenue of $26 per year for each kilowatt of demand and that the heating load returned $43 per year for each kilowatt of demand,—indicating very clearly the inherently high load factor of industrial heating equipment.

1. A. I. E. E. Journal, Vol. XLIV, May, p. 458.

A HIGH-FREQUENCY INDUCTION FURNACE PLANT FOR THE MANUFACTURE OF SPECIAL ALLOYS

(BRACE)

ST. LOUIS, MO., ARRIL 17, 1925

H. N. Shaw: I should like to ask what the over-all efficiency of that high-frequency induction furnace really is? That is, the ratio of the B. t. u. put into the motor to the B. t. u. actually developed in the iron of the furnace. It seems to me that there would be other applications if that efficiency is at all high. Offhand, it would seem to me to be quite low.

P. H. Brace: In reply to Mr. Shaw's question as to the over-all thermal efficiency of the high-frequency furnace and generator installation, I should say that for an input of approximately 150 kw. to the motor we get slightly more than 100 kw. out of the generator. Twenty kw. are lost in the copper of the inductor coil of the furnace and five kw. in the condensers, thus leaving a balance of about 75 kw., which is converted into heat in the charge. This is not a particularly high thermal efficiency as compared with that obtained with large arc furnaces, but with the present type of furnace we can easily do things that are not practicable with other types. We have complete control of our furnace atmosphere and in our particular design of furnace we have avoided all the troubles due to the casting of ingots and done away with all of the heavy labor. The use of electrolytic metals has eliminated the fire refining steps required in ordinary steel-making processes and we have attained a product which we were unable to secure in any other way. I might emphasize the fact that this plant is more than a plaything; we are producing approximately 40,000 lb. per month of one particular material.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

STANDARDIZATION AND THE PART IT HAS PLAYED IN THE DEVELOPMENT OF THE INCANDESCENT LAMP

Standardization has been cited many times as one of the reasons for the extensive application and low cost of an article which is widely used by the public. It has become a factor of ever increasing importance to modern industry and is one of the foundation stones upon which large industrial and commercial enterprises are based. In the manufacture of everything from structual steel and automobiles to watches and chewing gum, it plays a large and important part—and in the lamp manufacturing industry, along with all the others, it has become a veritable watchword of progress and service.

Standardization is, by its very nature, a gradual process the beginning of which usually marks a definite stage in the development growth of any idea or invention. The beginning of such a development is woven about a simple device or set of conditions which constitutes the nucleus of the idea. As the application of the idea increases, various means of utilization are incorporated into its design. But each new means of utilization differs in some detail from all the others, so that a decided condition of non-standardization is produced. This condition, however, quite frequently uncovers the best design or at least the best tendency of design for the ultimate product and therefore has some value in the growth of the idea. The disadvantages of this condition are very burdensome to the manufacturer and are of course a cause of considerable annoyance and inconvenience to the user. Consequently, as the demand increases and as the greater cost of manufacturing, such a multiplicity of types and sizes, is realized, the manufacturer begins to take definite steps towards the simplification and standardization of his product. This requires a careful study and classification of the requirements which the product must meet in order that a maximum degree of service can be rendered to the user with a minimum number of types, sizes, finishes and the like.

The change from a condition of non-standardization to a definite standardization program sometimes appears to be a tremendous task because of the complexity which arises when renewal parts or repairs are required for the older equipment. However, that which looks to be a mountain at this period of development will be but a mole-hill to the ultimate growth and extensive use of the product, for a well organized and well planned standardization program will reduce the "changeover" period to insignificance as compared to the ultimate benefit which will result for the product. This is true because the sole purpose of standardization is to bring about greater economy or greater convenience in the application and use of the product.

Simplification and standardization have a very considerable influence on the unit cost of manufacture for obvious reasons. Moreover, by their aid, it is possible to make a greater concentration of effort towards the improvement of quality. Likewise, this same concentration of effort increases towards a better adaptation of the product to the function for which it was designed, and toward a wider application of the product for other uses.

Standardization also adds greatly to the ready availability of the article because a lesser number of sizes, etc., need be carried in stock and a larger number of the main sizes, etc., thus results. This enables the customer to receive the quickest of service and relieves him of the tedious process of submitting specifications and waiting for a considerable length of time for the fulfillment of his needs.

The modern method of quantity production would be absolutely impossible without standardization in one form or another.

In the lamp industry the first steps towards standardization were taken more than twenty-five years ago. They were concerned with the base of the lamp inasmuch as there were at least twenty-five types of sockets in use in the late nineties and over a hundred different varieties of bases. There was no need for this variety, for most of the bases and sockets were intended to render the same type of service. Consequently, about 1900, a number of lamp manufacturers met together to determine the one best type of socket and base for general use in this country. The socket for the present form of screw thread was then one of the three in most common use and obviously this fact was

one of the chief factors involved in its selection. Moreover, because of its simplicity and its low cost of manufacture, it seemed to posses some advantages over the other types of which it was estimated that there were some five million in use at that time. The difficulty of changing these five million sockets so that the Edison screw-base could be used exclusively seemed rather large, but after a definite program had been put into operation, the results surprised even the most optimistic. To be sure, the change was effected rather gradually but no great amount of difficulty was encountered, since the lamps with the standard base were sold with socket adapters for the same price as the type which was to be eliminated. By this means and by the gradual scrapping of the old sockets, it was but a few years before the demand for anything but a lamp with a standard base, had decreased to an almost negligible amount.

With the adoption of one type of socket and base made standard for all general lighting service, the importance of standardizing the essential dimensions of the base and socket shell diameters, and the depth and form of thread, became apparent, and standards were soon promulgated for the screw-thread bases by the American Society of Mechanical Engineers.

Because of the different sizes of lamps required for the various classes of service, such as general interior illumination, street lighting, flashlights, and small decorative fixtures, it of course became necessary to have more than just one size of base. However, even though these four sizes of screw base all serve in different fields, each one is perfectly standardized within its own field.

Because of the vibration encountered and the necessary accuracy in the position of the light center, the automotive lighting field presents a different problem. Nevertheless, even in this field there are but two standard types of bases.

The standardization of lamp voltages was another problem encountered in the lamp industry. In the days of the carbon lamp the irregularities in the manufacture of the filaments were such that it was difficult to make any individual lamp conform to any definite voltage specifications. Consequently the completed lamps were tested to an approximate voltage rating and sold accordingly. This then made it possible to obtain lamps for each individual voltage from 100 to 130 volts, for the more common uses. The central stations in various communities operated on different voltages; hence the lamps which happened to fall within any particular voltage range were used in the particular community which maintained a corresponding voltage. Thus all lamps were used on voltages approximating their own rating.

Previous to 1910 no effort was made to restrain the spread of the voltages within the 100- to 130-volt range, but by 1913 it had become possible to manufacture lamps accurately to any desired voltage, so that after this time, voltage standardization became a matter of considerable interest. Through cooperation with the companies producing and distributing electricity, 93 per cent of the lamps in this range are now supplied to circuits of either 110, 115 or 120 volts and the demand for lamps of some voltages has entirely ceased. Even today voltage standardization is not complete, but it is entirely possible that 115 volts will eventually become the standard voltage for all lamps intended for general lighting service. This will simplify certain parts of the process of manufacturing and distributing lamps and the economies thus attained will, in due course, react to the benefit of the ultimate consumer.

Today, practically every important type of lamp used for general lighting service may be obtained with one or more kinds of bulb finish. Moreover, the various bulb finishes have come through a period of general development the same as has been the case with the other items involved in the manufacture of lamps. These finishes, excepting the color-sprays and the like, have had for their object the diffusing of the light produced by the filament with partial concealment of the latter so as to reduce the glare resulting from the bare filament. Prior to this time, these objects have been accomplished by several different means among which were the outside sand frost, the outside spray frost, the use of white opal glass and the use of white enamel. All of these, with the exception of the opal glass, are finishes applied to the external surfaces of the bulb and are therefore more or less hard to keep clean.

The latest step in the development of the bulb finish has but recently been announced by the lamp manufacturers. It consists of an *inside frost.* This frost, inasmuch as it is inside the bulb, leaves the outside surface perfectly smooth—the same as the case with clear lamps—so that the lamp may be cleaned very easily. Moreover, the nature of the inside frost is such that the loss of light through cross reflections inside the bulb is much lower than in other types of diffusing bulbs; consequently the efficiency of transmission is more nearly that of a clear bulb than any other diffusing finish.

On July first, a new 25-watt frosted lamp, as shown in Fig. 1, was introduced to the buying public. The inside frost reduces glare quite considerably and even though a distinct bright spot is apparent in the center of the bulb when lighted, yet the relatively great contrast in brightness which exists when ordinary frosted or coated lamps are viewed against the darker background, is considerably reduced with the inside frosted lamp. Consequently little or no choice remains between these two types of lamps from the standpoint of glare.

Now, if real progress is to be made in the attempt to reduce materially the number of types of lamps regularly supplied, it would be advantageous to produce a lamp combining the best features of both the clear and

the frosted finish. This inside frosted lamp may perhaps be the solution of this problem.

A glance at a historical collection of incandescent lamps will reveal the large number of bulb shapes and filament constructions which have been used at one time or another. Even today, there is a considerable variety in bulb shapes. Therefore, if a single shape of

FIG. 1A—THE 25-WATT, A-19 BULB INSIDE FROSTED LAMP (UNLIGHTED)

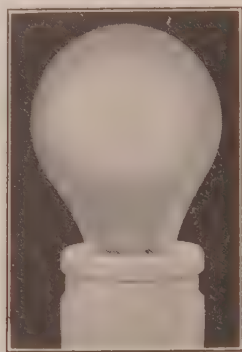


FIG. 1B—THE 25-WATT, A-19 BULB INSIDE FROSTED LAMP (LIGHTED)

bulb can be chosen to replace the several varieties now in use, another step towards complete standardization will have been made. The new lamp mentioned above has many possibilities when considered from this angle. It approaches more nearly a "drop shape" (such as would naturally be taken by the dab of glass from which

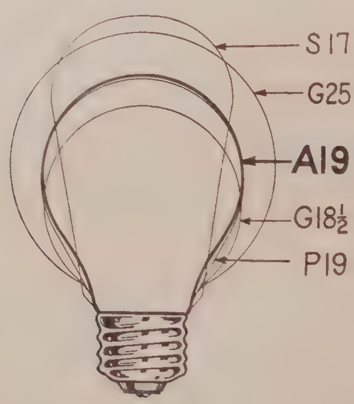


FIG. 2—HALF SCALE DRAWING SHOWING THAT THE NEW BULB SHAPE, A-19, FOR THE INSIDE FROSTED LAMP IS A PLEASING COMPROMISE OF THE VARIOUS SHAPES IT WILL EVENTUALLY REPLACE

it is blown), than any of the other bulbs, and it is for that reason very good from the standpoint of bulb production. In addition it is sturdy beside presenting a very pleasing appearance when viewed from an artistic point.

The greater mechanical strength of the coil filament lamps, first introduced as Mill Type lamps, and the higher efficiency which it is now possible to obtain from their use, has insured the coiled filament of being one of the important items in any further standardization developments.

In concluding, it might be interesting to note that lamp standardization in this country has, in spite of an increase in the former range in lamp sizes of from two to 32 c. p., as compared with the present range of from 10 to 1000 watts, reduced the total number of different varieties of the more common types of lamps, considering the various combinations of size, shape, voltage, and finish, from 55,000 to less than 400 and a further reduction in the number of sizes, etc., may be expected in the future.

BEAUTY OF DALLAS FOUNTAIN IS INCREASED BY COLORED LIGHTING

An electrically illuminated pan-chromatic fountain adorns the plaza in front of the Union Railroad Station at Dallas, Texas. This fountain consists of a large basin, fifty feet in diameter, inside of which is an elevated inner basin fourteen and one-half feet across. From the center of this basin a jet of water rises to a height of seventy-five feet, illumined to the very top by beams of light, constantly changing color, from four powerful incandescent searchlights concealed in a glass-covered room beneath the fountain. The effect is further enhanced by eight small jets rising from the large basin, each lighted from beneath by the colored light from a 500-watt lamp, while eight dolphins in the small basin throw streams toward the central jet.

Below the central basin is a circular room, eight by fourteen feet, separated from the fountain above it by a plate glass ceiling. In this compartment are the four big searchlights and the apparatus for operating the mechanism that changes the color screens and provides the variegation of colors. This apparatus is a motor-driven system of mechanisms—automatic in its operation. No attention is required except in case of an emergency. Entrance to the room where the floodlights and screens are located is effected by means of a passageway leading from the manhole in the larger basin. The water is pumped in such a way that it is used over and over again; hence the amount of water required for the running of the fountain is negligible.

While the Dallas fountain is not the first to employ colored floodlights, it is the first to use a total of five million-beam candle power, with changing color screens for the purpose.

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The Saratoga Springs Annual Convention June 22-26, 1925

The A. I. E. E. Annual Convention held last month at Saratoga Springs, N. Y., adds another success to the long list of important and notable gatherings of the Institute. There were about 900 members and guests registered, and both the technical sessions and the excursions, as well as the numerous entertainment features, were marked by an enthusiastic attendance. The committee reports and papers presented at the morning sessions drew out excellent discussions, much of which had been prepared in advance, and the Monday conferences of section delegates, officers and members of the Institute, for the consideration of Institute affairs, were entered into with an earnestness that bespeaks a most healthful condition of Institute activities.

Very effective preparation for the conduct of the convention was made by the Annual Convention Committee under the Chairmanship of J. R. Craighead, and the eight subcommittees of the general committee, each of which devoted itself to a particular feature of the convention details, are to be commended for the smooth functioning and lack of confusion which prevailed throughout the meeting.

Conference of Section Delegates

The first event of the Annual Convention was the Conference of Section Delegates held under the auspices of the Sections Committee, at morning and afternoon sessions on Monday, June 22.

The delegates in attendance at the convention were as follows:

Section	Delegate	Section	Delegate
Akron	J. T. Walther	New York	H. H. Barnes, Jr.
Atlanta	A. M. Schoen	Niagara Frontier	J. A. Johnson
Baltimore	W. B. Kouwenhoven	Oklahoma	E. R. Page
Boston	W. R. McCann	Philadelphia	C. D. Fawcett
Chicago	Carl Lee	Pittsburgh	M. E. Skinner
Cleveland	E. H. Martindale	Pittsfield	N. F. Hanley
Connecticut	W. A. Moore	Portland, Ore.	L. W. Ross
Denver	W. C. Duvall	Providence	F. N. Tompkins
Detroit	F. L. Snyder	Rochester	A. E. Soderholm
Erie	B. L. Delack	St. Louis	F. D. Lyon
Fort Wayne	A. B. Campbell	San Francisco	D. I. Cone
Indianapolis-Lafayette	D. C. Pyke	Schenectady	J. R. Craighead
Ithaca	P. M. Lincoln	Seattle	J. Hellenthal
Kansas City	Stanley I. Skinner	Springfield	R. P. King
Lehigh Valley	J. L. Beaver	Toledo	P. R. Knapp
Los Angeles	R. A. Hopkins	Toronto	H. C. Don Carlos
Lynn	B. W. St. Clair	Urbana	C. T. Knipp
Madison	R. G. Walter	Utah	H. W. Clark
Mexico	J. P. Ramirez	Vancouver	C. N. Beebe
Milwaukee	C. T. Evans	Washington	J. H. Ferry
Minnesota	A. G. Dewars	Worcester	S. M. Anson
Nebraska	P. M. McCullough		

The conference which was open to any members interested and was attended by a considerable number of officers and officers-elect, was presided over by Chairman Harold B. Smith of the Sections Committee, who opened the meeting with a brief statement regarding the purpose of the conference, after which he called upon President Osgood, President-Elect Pupin, and National Secretary Hutchinson, all of whom made brief addresses in which the importance of the conference to the membership at large, through the opportunity of making contributions to the solution of problems of the Institute, was emphasized.

Professor W. B. Kouwenhoven, who was chairman of the committee appointed by Professor Smith to prepare the program of the conference, which program had been sent out in advance, outlined briefly the scope of the conference. The topics then taken up for discussion included the following:

Student Branch activities, including methods of cooperation between the Branches and the Sections located in the same district.

A proposed by-law providing for the appointment of a "counselor" for each Branch from the electrical engineering faculty of the Institution in which the Branch is located, was discussed at length and was endorsed.

The relation of Institute Sections to other engineering organizations in the same city, and the methods of cooperation or affiliation of these various Sections and other organizations, were discussed at length, and there was an interchange of views of the representatives of the various Sections in which such affiliations have been established, including a discussion of the cost of such cooperation to the individual Sections. A recommendation was made to the Board of Directors that further study be given to the formulation of plans of procedure, particularly in bringing about affiliation of local Sections of the Founder Societies with local engineering organizations.

Regional meetings were discussed at length, and a resolution was adopted endorsing such meetings, provided the demand for such events originates in the regions in which the proposed meetings are to be held.

The desirability of annual visits of vice-presidents to the Sections within their respective Districts was emphasized.

National and regional prizes for worthy papers were discussed, and changes in the present policy suggested. The desirability of offering prizes for Student competition was also considered; and a resolution was adopted authorizing the appointment of a committee to draw up recommendations to the Board of Directors relating to the policy and procedure in connection with the award of prizes.

The conference closed with the adoption of the following resolution of appreciation of the services of President Osgood:

That the Section delegates assembled here, representing the entire membership of the Institute, express to President Farley Osgood their sincere appreciation, the appreciation of their membership and of all the Section executive officers, for the great interest, enthusiastic coordinating ability and individual effort which has resulted in outstanding advancement of all Sections in national Institute affairs.

In response, President Osgood expressed his hearty appreciation of the cooperation of the officers of Sections and the membership at large in carrying on the work of the Institute during his administration.

An abstract of the proceedings of the entire conference will be prepared and printed in pamphlet form as soon as possible after the reporter's transcript has been received, and will be mailed to all delegates in attendance, and all officers of Sections and Branches and of the national body. Any member interested may obtain a copy of this pamphlet, without charge, upon application to Institute headquarters, New York.

General Session

Tuesday morning all of the members and guests, including the ladies, assembled in general session to hear the President's Address and witness the presentation of Institute prizes for the best "first paper" and the best paper on "transmission" for the preceding year.

President Osgood's address was on the subject of "The Engineer and Civilization," and is printed on another page of this issue. The keynote of his address is the thought that the engineer should not devote himself exclusively to the technique of his profession, but should take a more active part in the world's work and become a dominant factor in the guiding of human affairs. The address was received with enthusiasm and warmly applauded.

The next order of business was the presentation of prizes for papers. President Osgood explained that on account of the large number of papers in competition, and the general high quality of all of them, it was not an easy matter for the committee to judge between them. After careful consideration the prizes were awarded as follows:

One hundred dollars and certificate to Murray F. Gardner for his first paper entitled *Corona Investigation on an Artificial Line.*

Fifty dollars each and certificates to R. D. Evans, and R. C. Bergvall joint authors of the Transmission paper, *Experimental Analysis of Stability and Power Limitations.*

The prizes were presented to the winners by President Osgood, who announced that, owing to the closeness of the competition, three "first papers" had been given honorable mention, as follows:

The Prediction of Insulation Failures in Transmission Lines, by H. C. Hamilton and R. W. Chadbourn, Boston, April, 1924.

Power Supply for Central Station Auxiliaries, by J. W. Dodge, Schenectady, February, 1924.

Fault Finding in Power Transmission Lines, by B. Aronoff, Cincinnati, September, 1924.

Following the presentation of prizes a recess was taken while the ladies withdrew for a trip to the McGregor golf links where a putting contest was held and luncheon served. The meeting then reconvened for the first technical session.

Technical Session No. 1

The first technical session, President Osgood presiding, was devoted to the presentation of Technical Committee reports, five of which were abstracted by the chairmen of the respective committees, as follows:

Present State of Transmission and Distribution Developments, by Committee on Power Transmission and Distribution, P. H. Thomas, Chairman;

Live Problems in Connection with Protection of Electrical Systems, by Committee on Protective Devices, H. R. Woodrow, Chairman;

Latest Design and Practise in Power Plants, by Committee on Power Generation, Vern E. Alden, Chairman;

Developments in Electrical Machine Design, by Committee on Electrical Machinery, H. M. Hobart, Chairman;

Precision Watthour Meters and High-Frequency Measurement, by Committee on Instruments and Measurements, A. E. Knowlton, Chairman;

The Activities in Research, by Committee on Research, John B. Whitehead, Chairman.

The time allotted to this session having expired, President Osgood announced the meeting adjourned until Wednesday morning, when the discussion of the foregoing reports would be made the first order of business.

Tuesday afternoon was devoted to golf, tennis, and a trip to the Sprite Creek remote-control hydroelectric station of the Adirondack Power & Light Company.

Professor Karapetoff's Recital

On Tuesday afternoon a large audience was delighted with a piano recital by Vladimir Karapetoff. Professor Karapetoff chose as his subjects some of the more popular of the classical compositions. In a very pleasing and illuminating way, he explained the meaning of the various themes of the music, in addition to rendering the following program most delightfully on the piano.

Second Movement from the "Pathetic" Sonata	*Beethoven*
To the Evening Star	*Wagner-Liszt*
Funeral March	*Chopin*
Kamenoi Ostrov	*Rubenstein*
Dream of Love, No. 3	*Liszt*

President's Reception

On Tuesday evening a reception was held in the beautiful Casino of Saratoga Springs. Following the reception dancing was enjoyed until a late hour. In the receiving line were President and Mrs. Farley Osgood, President-Elect M. I. Pupin and other officers of the Institute and their wives.

Music and a good floor were provided for dancing on every evening of the Convention and the interest never lessened among a very large proportion of those at the meeting.

Quite a number of those present played bridge and mah jong in the afternoons and evenings, in the rooms reserved for this purpose.

Technical Session No. 2

President Osgood called the session to order on Wednesday morning and asked for discussion on the Committee reports presented on Tuesday. A spirited discussion ensued which was participated in by Messrs. P. H. Chase, whose discussion was read by E. L. Sweet, F. W. Peek, Jr., A. L. Mudge, D. W. Roper, G. L. Knight, W. A. Del Mar, E. J. Burnham, J. F. Lincoln, T. A. E. Belt, G. B. McCabe, and R. E. Argersinger, with closures by Messrs. P. H. Thomas and J. B. Whitehead.

The next order of business was the presentation of the remaining committee reports which were presented in abstract by the chairman, as follows:

Developments in Applying Electricity to Industrial Uses, by Committee on General Power Applications, A. E. Waller, Chairman, read by title in the absence of the chairman;

Electricity's Progress in the Iron and Steel Industry, by Committee on Applications to Iron and Steel Production, F. B. Crosby, Chairman;

Advances in Use of Electricity in Mines, by Committee on Applications to Mining Work, F. L. Stone, Chairman, read by title in the absence of the chairman;

Rules and Personnel Problems of the Marine Field, by Committee on Applications to Marine Work, L. C. Brooks, Chairman, read by Mr. Beekman;

Progress in Diverse Lines of Electrochemistry and Electrometallurgy, by Committee on Electrochemistry and Electrometallurgy, George W. Vinal, Chairman;

A Year's Progress in Lighting, by Committee on Production and Application of Light, G. H. Stickney, Chairman;

Recent Advances in the Communication Art, by Committee on Communication, O. B. Blackwell, Chairman;

Revised Standards and the Organization of Standards Activities, by Standards Committee, H. S. Osborne, Chairman, read by title by Mr. Hobart in the Chairman's absence.

At the close of the above presentations it was necessary to adjourn the meeting promptly in order to take the special train for Schenectady for the inspection trip to the General Electric Company's plant.

Dinner in Honor of President-Elect Pupin

On Wednesday evening, June 24, a dinner was given by President Osgood in honor of President-Elect Pupin. Those present, in addition to the President and the guest of honor, included past presidents, officers, and officers-elect, and others as follows: C. A. Adams, H. H. Barnes, Jr., Edward Bennett, A. W. Berresford, J. M. Bryant, H. W. Eales, John H. Finney, M. M. Fowler, S. E. M. Henderson, H. M. Hobart, F. L. Hutchinson, H. A. Kidder, G. L. Knight, P. M. Lincoln, J. E. Macdonald, William McClellan, E. B. Merriam, L. F. Morehouse, A. G. Pierce, C. E. Skinner, Harold B. Smith, E. C. Stone, John B. Whitehead, R. B. Williamson.

The occasion afforded an opportunity to greet the President-Elect, and to discuss informally various matters relating to Institute policies.

Hydroelectric Development

On Wednesday evening the Convention convened to hear two addresses on hydroelectric developments. Mr. Samuel S. Wyer, consulting engineer, of Columbus, Ohio, gave an interesting description of the "Power Possibilities at Muscle Shoals" based on his personal investigations and study of the entire project.

Following Mr. Wyer's address Mr. William S. Lee, of the Southern Power Company, described the plant and features of construction work on "The 540,000-H. P. Hydroelectric Development at Isle Maligne, Quebec.

At the close of the addresses the subject was thrown open to discussion, in which Messrs. W. L. Robb, R. G. Walter, W. McClellan and J. H. Finney took part.

Technical Session No. 3

In opening the third technical session Thursday morning, President Osgood first called for discussion of the Reports presented Wednesday morning. These were discussed by Messrs. L. T. Robinson, S. L. Gokhale, C. H. Sharp and H. E. Ramsey.

The regular program for Session No. 3 was then taken up and the following papers were abstracted by their authors:

Engineering and Economic Elements of Two-Phase Five-Wire Distribution, by P. H. Chase;

The Oil Circuit Breaker Situation from an Operator's Viewpoint, by E. C. Stone;

The Quadrant Electrometer, by W. B. Kouwenhoven;

A New Method and Means for Measuring Dielectric Absorbtion, by R. E. Marbury;

An extensive discussion followed in which the following speakers took part: Messrs. A. H. Kehoe, R. A. Paine, H. R. Woodrow, W. S. Edsall, V. M. Marquis, J. B. Whitehead, Arnold Roth, E. C. Stone, D. M. Simons, W. F. Davidson, R. A. Neal, M. I. Pupin, P. H. Adams, L. T. Robinson, and H. Richter. This was followed by closures by the authors.

Technical Session No. 4

The fourth technical session was held Thursday morning, in parallel with Session No. 3, and was presided over by Mr. H. M. Hobart, Chairman of the Electrical Machinery Committee. Five papers were presented at this session as follows:

Separate Leakage Reactance of Transformer Windings, by O. G. C. Dahl;

Transformer Harmonics and Their Distribution, by O. G. C. Dahl;

A New Two-Phase to Six-Phase Transformer Connection, by A. Boyajian;

Resolution of Transformer Reactances into Primary and Secondary Reactances, by A. Boyajian;

Losses in Iron Under the Action of Superposed A-C. and D-C. Excitations, by O. E. Charlton and J. E. Jackson.

The discussions which followed were by Messrs. J. F. Peters, V. Karapetoff, J. D. Ball, R. G. McCurdy, A. C. Lanier, L. P. Ferris, C. T. Weller, O. R. Schurig, and J. K. Palueff. Closures were made by Messrs. A. Boyajian and J. E. Jackson.

Thursday afternoon was devoted to various sports and excursions, chief of which was a trip on Lake George provided by the Schenectady Section. This, in spite of a cold rain, was enjoyed by a party numbering about two hundred.

Educational Address

On Thursday evening the Convention listened to an interesting and instructive address by W. E. Wickenden, Director of Investiations for the S. P. E. E. Dr. Wickenden contrasted the methods of technical education in vogue in Great Britain and on the continent of Europe which are quite different, and both differ in many respects from the courses which have been developed in this country. The extensive investigation of this subject, however, is still under way, and no definite conclusions or recommendations can be predicated at this stage of the study.

The subject was thrown open for discussion at the close of Dr. Wickenden's address and some brief remarks were given by Prof. Karapetoff, Dr. Pupin and Dr. Pender.

Technical Session No. 5

The final technical session of the Convention was called to order Friday morning by President Osgood and the following papers were presented in abstract:

Study of Time Lag of the Needle Gap, by K. B. McEachron and E. J. Wade;

Oscillograph Solution of Electro-Mechanical Systems, by C. A. Nickle;

The Klydonograph and Its Application to Surge Investigations, by J. H. Cox and J. W. Legg;

Overvoltages on Transmission Systems Due to Dropping of Load, by E. J. Burnham;

The Loaded Submarine Telegraph Cable, by E. O. Buckley.

Discussion followed by Messrs. R. E. Doherty, E. E. F. Creighton, W. C. Peterman, E. E. Burgher, L. R. Golladay, read by J. F. Peters, E. B. Craft, R. D. Evans, D. W. Roper, K. B. McEachron, L. T. Robinson and C. A. Perkins.

Closures were made by Messrs. K. B. McEachron, C. A. Nickle, J. H. Cox, and E. O. Buckley.

At the close of the session all in attendance assembled in the inner court of the hotel where a group photograph was taken.

This session marked the formal closing of the convention which reflected the greatest credit upon the Committee in charge. The personnel of the Convention Committee is as follows:

J. R. Craighead, *Chairman*, H. H. Dewey, N. F. Hanley, C. E. Mochrie, L. W. W. Morrow, F. W. Peters, L. T. Robinson, H. W. Samson, Harold B. Smith, W. A. Sredenschek, John B. Taylor, C. S. Van Dyke.

The Convention Committee had the assistance of the following ladies in planning and conducting the several entertainment features: Miss Edith Clarke, Mrs. James R. Craighead, Mrs. H. H. Dewey, Mrs. John A. Seede, Mrs. John B. Taylor, and Mrs. Thomas A. Worcester.

Inspection and Pleasure Trips

A trip by special train to Schenectady was taken on Wednesday through the hospitality of the General Electric Company. Luncheon was served to the party in one of the company's large dining rooms. Then the many ladies who were present were taken by automobile to the Mohawk Golf Club to attend a musicale by the Rice String Quartet, after which tea was served. The men were conducted, in groups, through many of the shops of the plant.

Inspection trips were made by many during the week to three plants of the Adirondack Power and Light Company. The best attended trip was that to the Sprite Creek Station which is a remote-control hydroelectric plant. The other two trips mentioned were to the Amsterdam steam generating station and Rotterdam high-tension substation.

A trip was made on Thursday by most of the members and guests to beautiful Lake George. A special train conveyed the party to the lake where a steamer was waiting to take them for a two-hour ride through most attractive scenery.

On Monday morning the ladies took an interesting ride to the Saratoga and Schuyler battle grounds where they saw many historical scenes and monuments of the Revolutionary period.

The Golf Tournaments

Many availed themselves of the golf and tennis facilities provided at the splendid links of the MacGregor Golf Club and the beautiful turf courts of the Saratoga Country Club. Competition in all of the tournaments was close and interesting.

The ladies' putting contest was entered by over seventy players. After a tie was played off for first place, the first prize, a leather hat box, was won by Mrs. Howard Maxwell and the second prize, a luncheon set, by Mrs. R. C. Muir, while Mrs. George Cree won the third prize, a silver pitcher.

The Mershon Golf-Cup tournament, a 36-hole handicap contest, was won by C. E. Stephens with a net score of 147 (handicap 24 for 18 holes). In addition to having his name inscribed on the cup, Mr. Stephens was awarded a prize consisting of a portable automobile luncheon kit. The second prize in this event, a sliver cigarette case was won by A. L. Thuras with a net score of 150 (handicap 30). J. A. Seede, with a gross score of 176, (handicap 6), won the prize for the low gross score, a belt with a gold buckle. The Mershon golf cup has now names of ten winners inscribed upon it as follows: A. M. Schoen, J. C. Mock, E. W. Allen, L. F. Deming, A. A. Brown, M. G. Kennedy, Howard Maxwell, P. H. Chase, G. L. Knight and R. O. Bentley. According to the rules the contest must be won twice by a contestant before he may retain permanent possession of it. No one has yet won this event twice.

In the best-ball four-ball match the prizes for the low net score, two leather golf bags, were won by A. L. Thuras and V. A. Schlenker, with a net score of 69 (handicaps 30 each). The best gross score, 81, was made by H. H. Dewey and J. A. Seede, who won a dozen golf balls each.

The "Kickers Handicap" was won by P. M. Lincoln with a net score of 75 (handicap 35). Two vacuum bottles were the prize.

The prize for the selected-score contest, a dressing case, was won by R. O. Bentley, who made the best net score for nine holes. His score was a net 32 (37 gross minus ¼ of his handicap).

The Tennis Tournaments

The Mershon Cup for tennis was won for permanent possession by G. A. Sawin, who was the winner of the singles tennis tournament. As Mr. Sawin won this tournament in 1924 also, the cup is now his permanent property. One other name is on the cup; that of J. P. Nikonow, who won the tournament in 1923. In addition to the cup, Mr. Sawin received a prize of a wrist watch. The runner-up in the singles was Felix Wunsch who received a diamond scarf pin.

The doubles tennis tournament was won by G. A. Sawin and H. R. Summerhayes, each of whom received a pair of gold cuff links. The runners-up in the event, R. L. Shepherd and E. H. Hubert, received silver cigarette cases. Both of the tennis tournaments were handicap affairs which made them very closely contested.

Prizes for Long-Distance Driving to the Convention

Prizes were given to members who drove the longest distance to the Convention in cars. E. R. Page, who drove a distance of 1807 miles from Norman, Okla., received the prize for driving an automobile the longest distance. J. D. Ball received a prize for driving a Ford farthest. He came from Milwaukee, a distance of 1062 miles. A. V. Karpov also received a prize for driving a Ford from Pittsburgh, a distance of 530 miles.

Pacific Coast Convention Plans

Plans for the Pacific Coast Convention are progressing with gratifying promise. The meeting will be held in Seattle, starting September 15th and lasting four days.

City Distribution will be one of the most prominent subjects on the program, and a number of papers giving information on various types of distribution systems operating in the several sections of the country will be presented.

Transmission will also be featured, particularly long-distance and high-voltage transmission, the problem of stability to be treated by prominent engineers.

A symposium on *hydroelectric power development* on the Pacific Northwest is planned as another feature of the meeting, and a number of other interesting subjects will be covered by papers on the program. There will also be several trips and events of entertainment on the schedule.

The committee in charge is as follows: Messrs. G. E. Quinan. Chairman, C. N. Beebe, Hiram W. Clark, Harry P. Cramer, E. J. DesCamp, W. C. DuVall, F. R. George, John Harisberger, C. A. Heinze, Joseph Hellenthal, Charles A. Lund, C. E. Magnusson, James S. McNair, C. E. Mong, L. W. W. Morrow and C. R. Wallis.

Summer Meeting of the Society of Civil Engineers

Men of national prominence will attend and participate in the program of the Summer meeting of the Civil Engineers, July 8-10, at Salt Lake City. The History of Irrigation Development of the West in its varying phases will be discussed by such men as Elwood Mead, Commissioner of Irrigation; Col. William Kelley, for several years chief engineer of the Federal Power Commission; John A. Widtsoe, member of the commission recently appointed to study reclamation needs; Samuel Fortier, Associate Chief of the Division of Agricultural Engineering, U. S. Agricultural Dept., and Frederick Newell and Arthur P. Davis who, between them, have headed the United States Reclamation service for the past twenty years. Many other subjects of importance to the West, such as power, steam regulation and highway and city planning, will also be discussed by men prominent in their respective fields. Thursday afternoon, and Friday, July 10th, will be devoted to sight seeing, inspection trips and general diversion. At noon on Wednesday July 8th, the meeting will adjourn to attend an organ recital in the famous Mormon Tabernacle, after which opportunity will be given to the engineers to inspect the unique construction of the roof of this edifice.

Meeting of the American Chemical Society

The seventieth meeting of the American Chemical Society will be held at Los Angeles during the week of August 8th; it is expected that more than 1500 scientists from the United States and Canada will attend. The central theme will be "The Mystery of Matter," and at the big general meeting Doctor W. R. Whitney, director of the research laboratories of the General Electric Company, will deliver what is announced as an "illustrated experimental address" on "Matter—Is there Anything in It?" Other speakers at the meeting will be Prof. Alexander Findley of the University of Aberdeen, Scotland and Prof. Alonzo B. Taylor of Stanford University. Many interesting subjects have been chosen for presentation and discussion, including several agricultural applications of the profession, German competition with the American wood alcohol industry, the progress of dyes in treating diseases, developments in the quest of a new and cheaper motor fuel and the general expansion of the chemical science both in industry and education.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the United States Hotel, Saratoga Springs, N. Y., on Thursday, June 25, 1925.

There were present: President Farley Osgood, Newark, N. J.—Vice-Presidents, H. E. Bussey, Atlanta; Harold B. Smith, Worcester, Mass.; J. E. Macdonald, Los Angeles; S. E. M. Henderson, Toronto; H. W. Eales, St. Louis; L. F. Morehouse, New York—Managers, G. L. Knight, Brooklyn, N. Y.; H. M. Hobart, E. B. Merriam, Schenectady; R. B. Williamson, Milwaukee; J. M. Bryant, Austin, Tex.; A. G. Pierce, Cleveland; John B. Whitehead, Baltimore—National Secretary F. L. Hutchinson, New York. Present by invitation. Past-Presidents Comfort A. Adams, Cambridge, Mass.; A. W. Berresford, Niagara Falls—President-elect M. I. Pupin, New York—Managers-elect, M. M. Fowler, Chicago; E. C. Stone, Pittsburgh; and C. E. Skinner, Chairman, American Engineering Standards Committee, Pittsburgh.

A report of meetings of the Board of Examiners held June 15 and 19, 1925, was presented and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following actions were taken upon pending applications: 75 Students were ordered enrolled; 352 applicants were elected to the grade of Associate; 16 applicants were elected to the grade of Member; 1 applicant was elected to the grade of Fellow; 37 applicants were transferred to the grade of Member; 8 applicants were transferred to the grade of Fellow.

The Board ratified the approval by the Finance Committee for payment, of monthly bills amounting to $25,863.43.

The Secretary reported 1138 members delinquent in the payment of dues for the fiscal year ending April 30, 1925. The Board directed that the usual efforts be continued to collect these dues, through the Secretary's office and by bringing the list to the attention of the Section officers concerned.

Amendments to the by-laws, as formulated by the Committee on Revision of By-laws, and sent out to the Board members in advance, were adopted. These amendments include the necessary procedure for bringing into effect the constitutional amendments which were adopted on May 15, providing, among other things, for a revision of the election procedure of the Institute.

These amended by-laws will be printed in pamphlet form during the month of July, and will be available to any member without charge, upon receipt of request at Institute headquarters, New York.

A progress report was made by Mr. H. M. Hobart, who, in accordance with previous actions of the Board, has been formulating suggestions relating to the policy, procedure, and coordination of the technical activities of the Institute. On Mr. Hobart's recommendation, the Board authorized the appointment of a committee of five members of the Board to carry on this work by giving consideration to all communications that have been, and that may be, received relative to this matter, and to make a report, with recommendations to the Board of Directors, at a later date.

Upon the recommendation of the Standards Committee, the Board approved Institute Standards on the following subjects: "Standards for Direct-Current Rotating Machinery, Generators and Motors"—Section 5; "Standards for Alternators, Synchronous Motors and Synchronous Machines in General"—Section 7; "Standards for Railway Motors"—Section 11; "Standards for Railway Control and Mine Locomotive Control Apparatus"—Section 16; "Standards for Oil Circuit Breakers"—Section 19; "Standards for Disconnecting and Horn Gap Switches"—Section 22; "Standards for Resistance Welding Apparatus"—Section 39; "Insulator Test Specification Standards"—Section 41; also five new "Terms" and a "Table of Symbols and Abbreviations" which are to become a part of Section 2 of the Standards, entitled "Standard Definitions and Symbols."

The resignation of Past President Harris J. Ryan as an Institute representative on the John Fritz Medal Board of Award was received, and Past President Gano Dunn was appointed to fill Dr. Ryan's unexpired term.

An invitation to appoint a representative on the Advisory Board of the American Year Book, a publication which was discontinued several years ago and has now been revived, was accepted, and Mr. Edward Caldwell was appointed.

Other matters of importance were discussed, reference to which may be found in this and future issues of the JOURNAL.

At the close of the meeting, the Directors present expressed their hearty appreciation of the services of President Osgood, and their pleasure at the opportunity that they had enjoyed of cooperating with him, during his administration; and in response, President Osgood thanked the members of the Board for the support given to him during his term as president and expressed his appreciation of being associated with them during the year.

Jonas Waldo Smith Receives 1925 Washington Award Commission

The Commission of Washington Award for 1925 was voted to Jonas Waldo Smith, Consulting Engineer for the Board of Water Supply, New York City. Presentation of the award was made at the 55th Annual Dinner of the Western Society of Engineers, Chicago, June 3, 1925. The award was made to Mr. Smith "For the rare combination of vision, technical skill, administrative ability and courageous leadership in engineering." Following a wide experience in similar fields, Mr. Smith, in 1905, was made Chief Engineer of the world's largest water works, the additional supply for the City of New York from the Catskill Mountains. Up to 1917 this project involved the expenditure of $175,000,000 for work performed on schedule time and this was at a cost of about $9,000,000 less than the original estimates.

The award is made annually by a committee composed of nine representatives of the Western Society of Engineers and two each from the A. S. C. E., the A. I. M. E., the A. S. M. E. and the A. I. E. E. The award of the medal was established in 1917 by Past President J. W. Alvord of the Western Society "to be annually presented to an engineer whose work in some special instance, or whose services in general have been noteworthy for their merit in promoting the public good."

The 1925 award is the fourth; the first was made in 1919 to Herbert Hoover, the second in 1922 to Capt. Robert W. Hunt, and the third in 1924 to Arthur N. Talbot.

Associated Engineers of Spokane Pay Annual Visits

Adhering to their established custom, the Associated Engineers of Spokane, on May 1st, 1925, paid their annual visit to the University of Idaho and the State College of Washington. Taking an early start, the party passed the night at Lewiston and spent the following morning in sightseeing which included inspection of interesting power developments there. About noon on May 2d, they arrived at the State College, Pullman, Washington, where further activities were enjoyed. At both Universities interesting exhibits had been prepared by the students of the various departments, with entire responsibility upon them for collection, arrangements and success of the undertaking. The interest taken by this group of Associated Engineers, miners, foresters and architects in the work of the Universities is most commendable and should have strong and favorable influence on the respective student bodies, toward stimulating activity.

District Paper Prize for 1924

Doctor H. B. Dwight of the Canadian Westinghouse Company has been awarded the 1924 Geographical District prize of District No. 10 (Canada), for his paper entitled "Questions of Practical Interest in Transmission and Distribution," as submitted to the Toronto Section on November 21, 1924.

National Government Educates for Engineering

Members of the American Institute of Electrical Engineers and readers of its JOURNAL will be interested to know that the National Government has educated for the engineering profession hundreds of men, and that the Government still has in training for this profession many hundreds more.

These men are in training in the leading colleges and universities of the country and are scattered from coast to coast. The chief cities in which this training is given, and the number of men being trained for electrical engineers in these cities, are as follows: Boston, 24; New York, 11; Philadelphia, 4; Washington, D. C., 2; Atlanta, 1; Cincinnati, 12; Chicago, 27; St. Louis, 4; Minneapolis 18; San Francisco, 11; Los Angeles, 9, and Denver, 26.

This educating of men for the engineering profession on the part of the National Government is a part of the work of training and educating the soldiers who served in the American Forces during the World War and who received wounds and disabilities that prevented them from working at the same occupations that they worked at before the war. This work is now entering upon its last phase and will terminate on June 30, 1926.

The scope of the work of our Government in endeavoring to rehabilitate the disabled soldiers of the World War is realized by few. It has been going on since 1918. A total of 177,823 disabled soldiers has entered upon this training and education under the National Government's jurisdiction. These men are from every section of the country and have been trained for almost every conceivable occupation. Some have been enrolled in practically every university, college, and school in the country, while thousands of others have been trained "on the job" in the factories and workshops of the country. More than 92,000 have finished their training, have been declared rehabilitated, and practically all of these have been placed in the kind of employment for which they were trained. Some 25,000 men still remain in training, and, as stated above, several hundreds of these are studying engineering. A large number of them will be declared rehabilitated and ready for employment in the month of June due to their graduation from schools and colleges.

The National Government's work in connection with the rehabilitating of the disabled soldiers is carried on under the auspices of the United States Veterans' Bureau, a separate department of the Government directly under the control of the President. Under the Acts of Congress governing this rehabilitation work it is expected that the Bureau will train these men for vocations which they will be able to perform successfully. When the Bureau completes the training of these so-called "disabled veterans" they are in *no sense disabled so far as their ability and usefulness is concerned in carrying on in the specific line of work for which they have been trained. The Government aims to make them able men in their new vocations.*

The men who are being trained for the engineering profession are students in the best schools of the country. Much thought was given by the Bureau to the previous preparation, ability, and suitability of the men for the engineering profession before they were permitted to begin their course of study. The Bureau is proud to report that many of its students of engineering have carried off honor grades in various schools.

It is the duty of the Veterans' Bureau, as provided for under the Acts of Congress affecting this work, to secure employment for the men whom it has trained. This duty can be performed only through the cooperation of the general public. One of the brightest spots in the work of the United States Veterans' Bureau is the marked degree of cooperation that has been shown by the employing public in taking into its employ the thousands of men whom the Government has trained and rehabilitated.

It is especially difficult to find employment for persons who are being trained for the various professions. The Bureau feels certain that it is appealing to a most receptive portion of the general public when it asks the members of the American Institute of Electrical Engineers to render cooperation and assistance to the Government in the employment of men whom it has trained for the engineering profession.

As the Bureau has branch offices in practically all of the large cities of the United States, effective contact can be made by those interested with any one of these offices. Or correspondence will be heartily welcomed by the United States Veterans' Bureau, Central Office, Washington, D. C., from members of the engineering profession who might favorably consider taking into their offices one or more of these deserving men who are ambitious for success in engineering.—*Brigadier General Frank T. Hines, Director, U. S. Veteran's Bureau.*

American Engineering Standards Committee

ILLUMINATING ENGINEERING NOMENCLATURE AND PHOTOMETRIC STANDARDS

A revision of the Illuminating Engineering Nomenclature and Photometric Standards has been approved by the American Engineering Standards Committee as "American Standard." The work includes the definition of present terms as well as a few additional ones used in illuminating engineering and photometry, together with the formulation of general principles to govern the measurement of light and illumination and the application of such measurements in practise.

In view of its international standing the "Lambert," definition of the unit for brightness, together with a number of other definitions of units used in light measurements, has been retained as previously defined. Conversion factors for various working units are also given.

This work, sponsored by the Illuminating Engineering Society, was carried out by a sectional committee including members from the Illuminating Engineers, the American Gas Association, American Institute of Electrical Engineers, Bureau of Standards, U. S. National Committee of the International Commission on Illumination, U. S. National Committee of the International Electrotechnical Commission, National Council of Lighting Fixture Manufacturers, National Electric Light Association, Optical Society of America, and some independent experts, E. C. Crittenden of the Bureau of Standards acting as Chairman.

STANDARD CONNECTIONS AND MARKING OF TERMINALS FOR ELECTRIC POWER APPARATUS

The recommendations of the Sectional Committee of the American Engineering Standards Committee on Standard Connections and Marking of Terminals of Electric Power Apparatus were approved as American Standards in April 1925 by the Main Committee of the A. E. S. A. The Sectional Committee under the sponsorship of the Electric Power Club, was made up of representatives from the following organizations: The Association of Edison Illuminating Companies, American Electric Railway Association, Associated Manufacturers of Electrical Supplies, National Electric Light Association, U. S. Bureau of Standards, Electric Power Club and American Institute of Electrical Engineers. Those interested in obtaining copies of this American Standard should write to Electric Power Club, B. F. Keith Building, Cleveland, Ohio. Price 35 cents.

Special Activities at University of Minnesota

At the request of and in cooperation with the North Central Division of the National Electric Light Association, plans are being made for conducting a school for meter-men at the University of Minnesota, to be held in the new Electrical Building during the week of September 21 to 26, 1925. Assistant Professor M. E. Todd will have immediate charge of the course, and

inquiries should be directed to the General Extension Division, University of Minnesota, Minneapolis, Minnesota. Before its public announcement, something over thirty men had expressed their intention of enrolling for this course.

A course on Electric Vehicles, will also be conducted during the first semester of 1925-26 by the General Extension Division of the University, the teacher being Harry S. Greiner, an electrical engineering graduate of the University, who has had many years of experience in the use of vehicle batteries and in the manufacture of trucks. Classes will be held in the Electrical Engineering Building, from September 28, 1925 to January 40, 1926; It is expected that this course will be quite similar to courses conducted in New York City and Chicago under the auspices of the Electric Light Association.

Appointments to Teaching Fellowships in the Department of Electrical Engineering at the University for the year 1925-1926 are as follows: Louis J. Schnell, B. S. E. E., graduate of University of Colorado; George F. Corcoran, B. S., graduate of South Dakota State College; I. C. Benson, B. S. E. E., graduate of University of Minnesota; Henry R. Reed, B. S. E. E., graduate of University of Minnesota.

UNIVERSITY OF MINNESOTA HOLDS ELECTRICAL SHOW

On April 24th and 25th the electrical engineers of the University of Minnesota held their biennial electrical show followed by a dance in the newly finished Electrical Engineering Building. Open house was kept on the 24th in conjunction with the annual Engineers' Day; in the afternoon the traditional dance and tea was held. The 25th was devoted entirely to the electrical show. It is estimated that over 400 people attended each day.

PERSONAL MENTION

G. E. SANDERSON of the New York Office of the Wagner Electric Company has been appointed Branch Manager of the Syracuse Office.

H. A. STORRS has severed his connections with the Modesto Irrigation District of Modesto, California.

A. H. GRISWOLD who was with the Southern California Telephone Co., Los Angeles, is now with the Pacific Tel. & Tel. Co., San Francisco.

H. GOODWIN, JR., is now associated with the Columbia Gas & Electric Company, New York City, having closed his connections with Messrs. Sanderson & Porter.

W. A. BARNES, formerly electrical engineer for Lander, Frary & Clark of New Britain, Connecticut, has joined the Wappler Electric Company of New York City.

B. A. IZ'UROFF, of Sity Tramway, Str. of Arch. Rossi, 1-3 Leningrad, Russia, removed to Moscow, with Armiansky per M. 6, Tramway Dept., "ETEZER."

HOWARD N. SNIDER, previously with the Milwaukee Electric Railway & Light Co., has entered the engineering department of the Compania Cubana de Electricidad, Amargura 23, Habana, Cuba.

H. A. GOULD has left the engineering department of the Southern California Edison Co. to join the Pacific Gas & Electric Company of San Francisco.

WILLIAM E. SEAMAN, assistant designing engineer for Stevens & Wood, Inc., has left them to accept a position in like capacity with H. L. Doherty & Co., New York City.

EDWARD F. ZIEGLER, previously with the Brooklyn Edison Company, is taking up new duties as senior designing engineer for the Philadelphia Company of Pittsburgh, Pa.

J. C. KARCHER recently left his position of research engineer with the Western Electric Company to accept the office of chief physicist for the Amerada Petroleum Company.

L. F. A. MITCHELL is now rendering engineering service in the factory of the Century Electric Co. having left Fairbanks, Morse & Co., St. Louis to assume these new duties.

ROBERT M. GARTH announces a change from the West Penn Power Co., Wilkinsburgh, Pa., to Knoxville, Tennessee, where he has joined the Knoxville Power & Light Company.

B. NIKIFOROFF is leaving the General Electric Company to accept a position as chief electrical engineer for the Mexican Light & Power Company, Calle Gunte, Mexico, D. F.

DAVID J. LORIA has resigned from the position of electrical designer of the Public Service Production Co. of New Jersey to go with the Duquesne Light Company, Pittsburgh, Pa.

J. H. KUHLMAN, B. A., E. E., has been promoted to Assistant Professor of Electrical Design at the University of Minnesota. Mr. Kuhlman is a graduate of State University of Iowa.

EDWARD L. CLARK who has been with the Pacific Commercial Company, Manila, P. I., for some time past will shortly take up work with the International General Electric Company, Schenectady, N. Y.

LEO D. FIRMAN, formerly appraisal engineer for Stockwell, Wilson & Linvill, Certified Public Accountants, has opened his own office in the Weightman Building, Philadelphia, as consulting electrical engineer.

L. EARL DEANE is about to return to the Cameroun, West Africa, to continue his work as engineer with the American Mission. Until July 4th, the date of his sailing, he will be located at Scotts Mills, Oregon.

A. H. SMITH for the past twenty-eight years identified with the Manufacturers' & Inventors' Electric Co. has recently purchased the building at 228 West Broadway for the purpose of developing special apparatus and engineering production.

J. H. TADLOCK has resigned his position as assistant to the resident engineer of the Stone & Webster's Baker River project, and has made connections with the General Electric Company, Portland, Ore., in the capacity of Sales Engineer.

J. B. NAYLER who has been identified with the engineering department of the Commonwealth Power Company of Jackson, Michigan, has made new connections with the Canadian Crocker Wheeler Co., St. Catherines, Ontario, Canada.

A. N. JOHNS has resigned from the position of chief engineer for the Associated Telephone Company to enter private practise with the Chester H. Loveland Engineers, San Francisco. Mr. Johns will be located in their branch office at Los Angeles.

R. J. S. PIGOTT is now consulting mechanical engineer for the Public Service Production Company, Terminal Building, Newark, N. J., having severed his connections with Stevens & Wood, Inc., the latter part of May, to take up his new work June first.

ROBERT MILLER, who has been appointed district manager for the mountain area of the General Electric Company's activities, will succeed Mr. Wheatlake and will be warmly welcomed by the members of the Denver Section to his new field of activity.

ROBERT G. TUGENBLAT has returned from a seven months stay in Europe, visiting Czechoslovakia, Austria, Germany, Holland and England in the interest of scientific investigation. He brings back to the States with him several new inventions and patents of engineering interest.

EDWIN R. MARTIN, who for several years has been Assistant Professor of Electric Power Engineering at the University of Minnesota, has resigned in order to take a position in the Industrial Power division of the Westinghouse Electric and Manufacturing Company at East Pittsburgh.

Dr. Geo. D. Shepardson, head of the Department of Electrical Engineering at the University of Minnesota, has been granted a sabbatical furlough for the year 1925-26, which will be spent largely in foreign travel. During his absence, Professor F. W. Springer will be acting head of the department.

C. E. Rose was recently appointed consulting engineer for the National Cottonseed Products Corporation. This Corporation operates approximately twenty-eight large cottonseed oil mills in Illinois, Kentucky, Tennessee, Louisiana, Mississippi and Arkansas, the Dixie Cottonseed oil mill at Memphis being counted by the Federal Government as the largest in the world. It is operated electrically by two 1250-kv-a. Curtis turbines and G. E. generators.

B. C. J. Wheatlake, who has for thirteen years been connected with the General Electric Company in Denver and for the past several years District Manager of the Central Station Department of that company, has been transferred to Salt Lake City to assume managership of the company there. His fellow members of the engineering profession will be pleased to learn of Mr. Wheatlake's promotion but will regret the loss of so active a past chairman in the Denver Section.

J. E. Davidson of Omaha, Nebraska was, at its recent convention, elected president of the National Electric Light Association. Mr. Davidson is well known for his achievements in the profession, his reputation being international as well as national, he having won renown last year when, as chairman of the N. E. L. A.'s lighting educational committee, he sponsored and directed the International Better Home Lighting campaign and essay contest in the United States and Canada.

E. F. W. Alexanderson, consulting engineer of the General Electric Company and inventor of the Alexanderson high-frequency alternator which made trans-oceanic radio communication possible, sailed June 13 to attend the official inauguration of Sweden's new high-powered radio station at Varberg. This will take place July 2, and will be attended by Gustav V, King of Sweden. Two of the Alexanderson alternators have been installed in this station which has already been in direct communication with Radio Central, the Radio Corporation station on Long Island. Mr. Alexanderson will return, reaching New York, about July 20.

Ellis T. Batcheller, former secretary of the Seattle Section, has joined with O. H. Kneen in the formation of a new firm of consulting engineers, Batcheller & Kneen, Inc., with offices in the Dexter Horton Building, Seattle. Mr. Batcheller has been active in the power industry for the last fifteen years, having specialized in hydroelectric development, steam power generation, transmission and application.

G. W. Swenson, B. S., E. E., has been promoted to Assistant Professor of Telegraph and Telephone Engineering at the University of Minnesota. After graduating from this University, Mr. Swenson was connected with the Northwestern Bell Telephone Exchange Company and with the Western Electric Company, later serving as an instructor in vocational training of drafted men during the war. He then became an instructor in Electrical Engineering at the University of Minnesota, specializing in electrical communication.

Elmer W. Johnson, B. S., E. E., M. E., has been transferred and promoted from Instructor in Mathematics and Mechanics to Assistant Professor of Electric Power Engineering at the University of Minnesota. After graduation from the University of Minnesota, Mr. Johnson spent two years with the Westinghouse Electric and Manufacturing Company at Pittsburgh, one year of which was in the Railway Application Section. This was followed by a year of experience in the substations and shops of the Chicago, Milwaukee and Puget Sound Railway electrification. He spent over a year during the war in charge of electrical construction and maintenance at the docks at Brest, France, including the adjacent railway yards and supply depot. For two years he was assistant electrical engineer with the Northern States Power Company, continuing with special problems for them while engaged as an instructor at the University of Minnesota.

Obituary

Leonardo de Albuquerque Cavalcanti, while supervising the termination of the trolley line for the second electrified section of the Paulista Railway, Brazil, the construction of which he had just completed, came in contact with a high-voltage line and was instantly killed. Born in Sao Paulo, Brazil, July 1, 1892, Mr. Cavalcanti's early education was through the Bacheral in Science at Saint Louis College, Brazil. He next took a four years' course in Civil Engineering at McKenzie College, Brazil, before coming to the United States to enter a three years' post graduate course in the School of Electrical Engineering, Princeton University. In 1916, the Charles Ira Young medal for Electrical Research was awarded him. This was the year of his graduation from Princeton and for the thesis presented for his electrical engineering degree he chose the subject of investigation to determine the thermal and electrical conductivity separately, and also the ratio of the thermal to the electrical conductivity of pure Acheson graphite by the Kohlrausch method. In the summer of 1914, he joined the Western Electric Company at Cicero, Illinois, and for a year, before returning to his own country was with the Westinghouse Electric & Mfg. Co. of Pittsburgh. Upon his return to South America, he became assistant engineer for the Cia. Compineneira de Luz e Forca and later, in 1920, was asked by the superintendent of the Paulista Railway to take charge of a new electrification construction plant. It was here that he met his death. Mr. Cavalcanti became an Associate of the Institute in 1916, the year of his graduation from Princeton, and his activities in the profession seemed to promise much.

Cecil Winfield King died May 24th at the Seton Hospital, from the effects of gassing and shell shock sustained during the World War. Mr. King was but thirty years of age. He was a native of Tottenville, New York, and his early engineering training was acquired in the Stuyvesant High School, the Y. M. C. A. and the International Correspondence School. His first practical position was with the Western Electric Company of New York in 1912, but in 1913 he left to go with the Richmond Light & Railroad Company, Livingston, S. I., where for nine months he was accomplishing meter and arc light study and tests. In 1914 he joined the New York Edison Company on substation meter installation work, but changed in 1915 to identify himself with the General Electric Maintenance Department of the Interborough Rapid Transit. For three years he was with the Otis Elevator Company at Yonkers, taking a five months' student course on the manufacture and assembling of machines, foundry, armature work, stator and rotor windings; wiring and testing a-c. and d-c. controllers, the assembling and testing of all kinds of d-c. motors, single-phase motors and induction motors, including double stator, two-speed types manufactured for ship propulsion during the war. This course also included study of production, cost and estimating, and specifying work. Mr. King's latest connection was in the capacity of electrical designer for the Electric Bond and Share Company, New York City. He joined the Institute in 1921 as an Associate and was making marked progress in the profession when his untimely death occurred.

Albert Edward Winchester, Electrical Commissioner of the City of South Norwalk, Connecticut, and Fellow of the Institute since 1912, died suddenly June 30th, 1925. Of New England and Southern ancestry, Mr. Winchester was born in Marietta, Ohio, April 19th, 1867; his father was an artist, editor and inventor and his mother a prominent educator. He was a direct descendent of the Colonial Governor, Belcher. In 1871 he accompanied his mother to her home in Ithaca, New York,

where he attended school until, in 1876, New York City became their home. Here, at the age of ten, he became an office boy for a Wall Street law firm. In 1881 he returned to Mexico with his mother; he was then fourteen years of age, and there being no suitable schools in Mexico and the boy having evinced an almost insatiable zeal for constructive mechanics and keen comprehension of the scientific, he was apprenticed to the Mexican Central Railway. In 1883 he returned to the United States to take a special course in engineering and drafting under private tutorship. In 1886 he became a member of the engineering staff of the parent Edison Company for isolated central station electric lighting. He was with the Sprague Electric Company through varying changes and until 1893 was draftsman, construction engineer and inspector and supervisor of work for the General Electric Co. From that year until 1896 he was construction superintendent and director of the Electrical and Mechanical Engineering Company of New York, becoming, in 1892, Electrical Engineer for the City of South Norwalk, organizing and building one of the most successful municipal lighting plants ever in operation. Mr. Winchester was a member of the National Civic Federation Commission which investigated public and private ownerships of public utilities both here and abroad, and for five months acted as electrical expert to the commission in Great Britain. While abroad, Mr. Winchester was also a United States delegate of the A. I. E. E. to the International Congress of electrical engineers, London. His career was a series of successful undertakings from childhood up, and his death takes from the profession a man of no small amount of promise.

Harry B. Marshall, president of the Marshall Electric Company, St. Louis, Missouri, while on a recent motor trip with his wife, was struck by a train four miles south of Owosso, Michigan, and killed, living only a short time after the accident. Mrs. Marshall was killed instantly.

Mr. Marshall was born in Chicago, December 5th, 1883 and in 1905 earned his B. S. degree from the Armour Institute of Technology, from which he also had an E. E. degree. During his college term, he was affiliated with the Electric Storage Battery Company, for which he became manager of the St. Louis office in 1909. Here he served until 1922, when his managership was transferred to the Railway Department of the same company, Philadelphia, Pa. In 1923, Mr. Marshall returned to Chicago to establish his own company. He was president of this at the time of his death. The success with which his work met convincingly demonstrates the loss through his death.

Book Review

TECHNICAL TERMS FOR ELECTRICAL COMMUNICATION

A small, handy English-German dictionary for German speaking people interested primarily in the field of communication has been prepared by G. Sattelberg, of the Telegraphentechnische Reichsamt, Berlin, and is available through the publisher, Julius Springer, Berlin, Germany. This dictionary has been developed from such references as Steinmetz's Theory of Calculation of A-C Phenomena; Morecroft's Principles of Radio Communication; Marconi's Yearbook; Works of the British Engineering Standards Association; Journal of the Institution of Electrical Engineers, the *Radio Review* of London, the JOURNAL of the A. I. E. E. and numerous other well-known sources of technical information, and should be a valuable compilation to those interested.

DESCRIPTIVE OF MUSCLE SHOALS

A unique compilation entitled "America's Greatest Dam" has just been brought out by William Benjamin West, B. S., Alabama Polytechnic Institute, Associate Editor of the Commercial News Record, Associate Member of the Society of Industrial Engineers and Associate of the Institute.

The book includes a profusion of photographs, illustrative of the Muscle Shoals section,—most of them taken by Mr. West, himself,—with accompanying descriptive text. Primarily, it has for its purpose presenting, in simple and concise form, fundamentals of the nitrate production and matters relative to the Muscle Shoals situation, in a desire to be of practical service to those considering a solution of the present problem, especially those afforded no opportunity of personally visiting the location itself to acquaint themselves with the plants and their operation.

The work is published in small album form, 11 by 8, cloth bound; it contains 64 pages with 54 illustrations. Price $2.00 net, postpaid. It has been termed "a lucid and entertaining narrative of Muscle Shoals," covering a general review of the project. Beside giving several sizable cuts and text on the Wilson Dam, various other units described in detail are Nitrate Plants No. 1 and 2, the process for manufacture of ammonium nitrate by the cyanamid process, capacities and units of Plant No. 2, with statistics; community statistics, the Tennessee River at Muscle Shoals, hydroelectric development, the spillway and navigation locks. Although the text content is brief, the profusion of illustrations in conjunction with such descriptive matter as is given makes the book a most interesting small volume.

Addresses Wanted

A list of names of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—Harry F. Beard, 1232 So. 51st St., Philadelphia, Pa.
2.—Paul H. Burkhart, S. S. S., Yale University, 10 Hillhouse Ave., New Haven, Conn.
3.—Paul W. Darlington, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
4.—Edwin P. Hill, c/o Radio Corp. of America, Bolinas, Calif.
5.—William B. Hoey, High Tension Supplies Co., Wilmington, Del.
6.—Chas. E. Knott, San Luis, Obispo, Calif.
7.—E. D. Law, Roderfield, W. Va.
8.—H. J. Mitchell, 42 Second St., Elmhurst, L. I., N. Y.
9.—David Ross, c/o Elec. Bond & Share Co., 71 Broadway, New York, N. Y.
10.—I. B. Watkins, 124 East Symmes St., Norman, Okla.

CHANGE OF MAILING ADDRESS OR BUSINESS RELATIONS

To facilitate the accuracy and proper entry of all addresses to be filed for Institute records, and for the greater convenience of our members and readers in furnishing same the following form is supplied.

ADDRESS CORRECTION BLANK

My present address for mail is

My present business connection is

(Title)

(Company name and address)

Signature

(To avoid misunderstanding please print or typewrite above information.)

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Telephonic Communication Over High-Voltage Transmission Lines, by W. V. Wolfe, Western Electric Co. Mr. Ralph Higgins, Ohio Insulator Works, also illustrated with slides condenser couplings developed for carrier-current on high-voltage lines. The following officers were elected: Chairman, Ralph Higgins; Secretary-Treasurer, G. L. Sanderson, May 22. Attendance 50.

Baltimore

Telephonic Investigation of Speech and Hearing, by Geo. B. Thomas, Bell Telephone Laboratories. Illustrated by moving pictures. May 15. Attendance 60.

Boston

Radio and The Radio Corporation of America, by E. F. W. Alexanderson, Radio Corporation of America. May 14. Attendance 300.

Social Meeting. The following officers were elected: Chairman, W. R. McCann; Vice-Chairman, J. W. Kidder; Secretary-Treasurer, W. H. Colburn. May 19. Attendance 234.

Chicago

Development of Hydroelectric Power, by Prof. D. W. Mead. Joint meeting with W. S. E. E. November 24. Attendance 285.

Survey of Current Progress in Radio Engineering, by Dr. J. H. Dellinger. Joint meeting with W. S. E. E. December 16. Attendance 260.

Automatic Substations in Steel Mills, by G. P. Wilson, Westinghouse Elec. & Mfg. Co. Joint meeting with W. S. E. E. and A. I. & S. E. January 26. Attendance 200.

Other Worlds than Ours, by Prof. F. R. Moulton. Dinner Meeting. March 7. Attendance 125.

The Mercury-Vapor Boiler and Turbine, by W. L. R. Emmett, General Electric Co. Joint meeting with W. S. E. E. March 24. Attendance 550.

Radium, by L. C. Schultz. Joint meeting with W. S. E. E. and A. I. M. & M. E. April 17. Attendance 150.

Protective Relays, by O. J. Bliss, Commonwealth Edison Co. Annual Meeting—joint with W. S. E. E. May 18. Attendance 200.

Cincinnati

Electrical Development in Japan, by S. Q. Hayes, Westinghouse Elec. & Mfg. Co. Illustrated by slides and motion pictures. May 14. Attendance 73.

The Points of View of a Professional Economist, by N. R. Whitney, Procter and Gamble Co. The following officers were elected; Chairman, H. C. Blackwell; Secretary-Treasurer, E. S. Fields. Dinner. June 11. Attendance 28.

Cleveland

Industrial Applications of Electricity in Mining, by C. H. Matthews, Westinghouse Elec. & Mfg. Co. April 23. Attendance 39.

Connecticut

Business Meeting. The following officers were elected: Chairman, A. A. Packard; Secretary-Treasurer, A. E. Knowlton. May 20. Attendance 35.

Causes of Interference in Radio Reception, by Prof. W. J. Williams, Rensselaer Polytechnic Institute. May 20. Attendance 1500.

Denver

Annual Meeting. Talk by John F. Stevens. The following officers were elected: Chairman, V. L. Board; Vice-Chairman, W. H. Edmunds; Secretary, R. B. Bonney. May 22. Attendance 500.

The Institute and the Engineering Profession, by Farley Osgood, National President, A. I. E. E. A short talk was also given by E. H. Hubert, Secretary, National Meetings and Papers Committee. May 27. Attendance 75.

Detroit-Ann Arbor

Lightning and Other High-Voltage Phenomena, by F. W. Peek, Jr., General Electric Co. The speaker, with the aid of a moving picture, described experiments conducted with the "lightning generator" which has a voltage range up to 2,000,000 volts and which is capable of simulating natural lightning in many respects. May 26. Attendance 175.

Erie

Australia and the Victorian Electric Railways, by R. T. Sawyer and W. R. Campbell. The following officers were elected: Chairman, H. J. Hansen; Secretary, L. H. Curtis. May 19. Attendance 60.

Fort Wayne

Our Debt to General Wayne, by J. B. Griswold. Annual Banquet. May 21. Attendance 53.

Indianapolis-Lafayette

Fractional Horse-Power Motors, by E. B. George, General Electric Co. Motion picture of a fractional horse-power motor assembling itself was shown. April 24. Attendance 45.

Ithaca

Power-Factor Correction in Industrial Plants, by L. P. Hyde, Westinghouse Elec. & Mfg. Co. May 15. Attendance 40.

Lehigh Valley

Application of Electricity in the Iron and Steel Industry, by John C. Reed, Bethlehem Steel Co. Joint meeting with the Engineers Club of the Lehigh Valley. May 8. Attendance 120.

Short Circuits and Transient Currents, by Professor V. Karapetoff, Cornell University. The following officers were elected: Chairman, W. H. Lesser; Secretary-Treasurer, George W. Brooks. May 29. Attendance 102.

Los Angeles

Transmission-Line Calculations, by E. R. Stauffacher, Southern California Edison Co.

The Design and Application of a New Form of Calculating Board, by L. F. Hunt, Southern California Edison Co., and

High-Voltage Oil Circuit Breakers, by J. F. Sturck, General Electric Co. May 12. Attendance 102.

Madison

The People and the Courts, by Judge E. Ray Stevens. Professor L. E. A. Kelso was elected Chairman of the Section for the coming year. May 13. Attendance 24.

Minnesota

Dinner Dance. The following officers were elected: Chairman, A. G. Dewars; Secretary, J. E. Sumpter. May 25. Attendance 96.

Nebraska

The Transmission of Pictures over Telephone Wires, by R. D. Parker, American Telephone & Telegraph Co. Illustrated. This lecture was given at Lincoln, Nebraska, on May 19 (attendance 39) and at Omaha on May 20 (attendance 118).

Philadelphia

Power-Factor Correction, by L. W. W. Morrow, Editor, *Electrical World*. May 11. Attendance 125.

Pittsburgh

Electric Power as a Factor in the European Situation, by C. M. Ripley, General Electric Co. The following officers were elected: Chairman, Geo. S. Humphrey; Secretary, W. C. Goodwin. Refreshments were served. May 12. Attendance 240.

Portland

Dance. May 20. Attendance 150.

Rochester

Automatic Train-Control Systems, by W. A. Reichard, General Railway Signal Co. The following officers were elected: Chairman, A. E. Soderholm; Vice-Chairman, Wesley M. Angle; Secretary-Treasurer, Earl C. Karker. May 15. Attendance 52.

Schenectady

The Institute and the Engineering Profession, by Farley Osgood, National President, A. I. E. E. April 24. Attendance 275.

Laws and Hypotheses of Electrical Science, by Dr. Michael I. Pupin. May 8. Attendance 450.

Annual Smoker. May 22. Attendance 225.

Seattle

The Engineering and Economical Features of the Proposed Columbia Basin Development, by Major Jos. Jacobs. April 15. Attendance 40.

Spokane

Trend in Design of Internal-Combustion Motors for Vehicular Uses, by Thos. Hutsell, The Hutsell Motor Co., and

The Future of Fuel Supply for Internal-Combustion Motors, by L. J. Pospisil, Washington Water Power Co. May 6. Attendance 26.

Springfield

Special Lighting Distributions as Applied to Industrial Lighting and Some Misconceptions in Lighting, by D. H. Tuck, Holophane Co. May 25. Attendance 53.

Utah

The Superpower System in the East, by Farley Osgood, National President, A. I. E. E. A short talk was also given by E. H. Hubert, Secretary, National Meetings and Papers Committee. May 25. Attendance 77.

Vancouver

Annual Meeting. The following officers were elected: Chairman A. Vilstrup; Secretary, C. W. Colvin. The meeting was preceded by a dinner. June 5. Attendance 31.

Washington

Transmission of Pictures by Telephone, by A. B. Clark, American Telephone and Telegraph Co. Illustrated by slides. The following officers were elected: Chairman, A. F. E. Horn; Vice-Chairman, H. B. Stabler; Secretary-Treasurer, L. E. Reed. Refreshments were served. May 12. Attendance 69.

Worcester

The Human Equation, by R. W. Adams, General Electric Co. May 21. Attendance 60.

BRANCH MEETINGS

Alabama Polytechnic Institute

Annual Banquet. A talk was given by Dr. Spright Dowell. April 14. Attendance 32.

Business Meeting. The following officers were elected: Chairman, C. W. McMullan; Vice-Chairman, J. A. Douglas; Secretary-Treasurer, W. E. Hooper. April 15. Attendance 18.

A motion picture, entitled "The Single Ridge," was shown. April 22. Attendance 19.

Business Meeting. April 29. Attendance 20.

University of Alabama

Business Meeting. February 4. Attendance 20.

Possibilities of the Use of 220-kv. Transmission Lines in the South, by S. E. Dawson, C. E. Comeaux and C. M. Lang, students. February 18. Attendance 24.

Inspection trip to the Alabama Power Company's Power Plant and the Tuscaloosa Ice Plant. February 25. Attendance 40.

Inspection trip to the Holt, Alabama, Plants of the Central Iron and Coal Co., the Central Iron Fountry Co., and the Semit Solvay Coke By-Product Co. March 4. Attendance 48.

A motion picture, entitled "The Test," was shown, accompanied by a talk by W. N. Nelson, General Electric Co. March 18. Attendance 21.

A talk was given by Professor F. R. Maxwell, on the coke by-product manufacture at the Semit Solvay Coke By-Product Company, and the processes used by the Central Iron and Coal Company and Central Iron Foundry Company in the manufacture of iron and steel for commercial uses. March 20. Attendance 20.

An Oil-Circuit Breaker Test, by Professor F. R. Maxwell. April 6. Attendance 12.

Slides of some water power developments were shown. April 18. Attendance 23.

Business Meeting. The following officers were elected: President, Cecil E. Rankin; Vice-President, Edwin T. Bates; Secretary-Treasurer, Sewell St. John. May 2. Attendance 16.

University of Arizona

Insulator Oils, by W. T. Voss, and

Lightning Protection, by R. A. Fulton. The following officers were elected: Chairman, C. A. Rollins; Vice-Chairman, W. T. Voss; Secretary-Treasurer, B. L. Jones. May 19. Attendance 14.

California Institute of Technology

Remote Control Metering,

Automatic Relay Practise, and

Group Feeder Systems, by Wm. Lewis. Refreshments were served. May 13. Attendance 18.

A motion picture of the Southern California Edison Company's Big Creek Development was shown, accompanied by a talk by Walter Blossom. May 21. Attendance 22.

Business Meeting. The following officers were elected: Chairman, W. A. Lewis; Secretary, Alfred Schueler. June 3. Attendance 22.

Carnegie Institute of Technology

Banquet. The following officers were elected: Chairman, G. L. LeBaron; Vice-Chairman, John Kinghorn; Secretary, H. E. Ashworth; Treasurer, A. F. Carson. May 21. Attendance 59.

University of Colorado

Business Meeting. The following officers were elected: President, Orville V. Miller; Vice-President, E. M. Paullin; Secretary, Lloyd E. Swedlund; Treasurer, Harlan M. Webber. June 3. Attendance 30.

University of Denver

Business Meeting. The following officers were elected: Chairman, Earl Reed; Vice-Chairman, Robert R. McLaughlin; Secretary-Treasurer, Ralph L. Kuhler; Corresponding Secretary, Alex. A. Ohlson. May 14. Attendance 21.

University of Florida

A film on automatic substations was shown. May 13. Attendance 18.

Georgia School of Technology

Protection of High-Tension Lines from Lightning Discharges, by C. E. Bennett, Georgia Railway and Power Co. The speaker illustrated his lecture, using a miniature line with model transformer and lightning arrester at 2200 volts. A Tesla coil was used for a superimposed potential. May 7. Attendance 200.

Annual Banquet. Talks were given by Messrs. T. W. Fitzgerald, T. G. Seidell, D. P. Savant, E. S. Hannaford, C. W. Cheatham and P. C. O'Shee. The following officers were elected: President, S. M. Thomas; Vice-President, L. C. Petri; Secretary-Treasurer, C. E. Burke. May 15. Attendance 50.

University of Idaho

Mr. Elmer E. Wyland, Mountain States Telegraph and Telephone Company, outlined the possibilities of student engineering positions with his company. The following officers were elected: President, R. C. Beam; Vice-President, N. J. Hutton; Secretary-Treasurer, James Gartin. May 26. Attendance 17.

Kansas State College

Management of Utilities, by Mr. Grosbeck, United Power and Light Co. May 12. Attendance 60.

University of Kansas

Short talks were given by Professors Shaad, Johnson and Anderson. Refreshments were served. May 20. Attendance 61.

Massachusetts Institute of Technology

Inspection trip to the Weymouth Station of the Boston Edison Co. The following officers for the Branch have been elected; Chairman, Stuart John; Vice-Chairman, Ole M. Hovgaard; Secretary, Helmut W. Geyer; Treasurer, Theodore Taylor. May 13. Attendance 30.

Electric Power Transmission, by R. D. Booth, Jackson & Moreland, Engineers. With the aid of slides the speaker outlined the methods of calculating transmission line characteristics. May 20. Attendance 23.

Michigan State College

Business Meeting. The following officers were elected: Chairman, H. C. Roberts; Secretary-Treasurer, R. A. Bailey. May 20. Attendance 28.

University of Michigan

Business Meeting. The following officers were elected: Chairman, Maurice H. Nelson; Vice-Chairman, Reuel D. Layman; Secretary, Stephen L. Burgwin; Treasurer, Roland A. Hoffman. May 21. Attendance 13.

School of Engineering of Milwaukee

Pictures Behind the Picture, by Frazer Jeffery, Allis-Chalmers Mfg. Co. May 14. Attendance 35.

Inspection trip to Eline's Power Plant. May 19. Attendance 40.

Inspection trip to the Falk Corporation. May 20. Attendance 35.

Inspection trip to the Lakeside Power Station. May 21. Attendance 45.

University of Minnesota

Exhibition and dance. April 24 and 25. (Further details elsewhere in this issue.)

University of Missouri

Business meeting. The following officers were elected: Chairman, Prof. M. P. Weinbach; Vice-Chairman, Arthur Glover; Corresponding Secretary, Louis Spraragen; Recording Secretary, Theo. Nolte; Treasurer, M. W. Levy. Two reels of moving pictures were shown. May 18. Attendance 10.

University of Nebraska

Business Meeting. The following officers were elected: President, M. E. LaBounty; Vice-President, W. T. Lammli, Secretary, C. J. Madsen; Treasurer, C. Reese. May 22.

College of the City of New York

A film on the manufacture of copper wire and cable was shown, accompanied by a short talk by Mr. Reeves. May 21. Attendance 40.

North Carolina State College

Business Meeting. The following officers were elected: President, F. P. Dickens; Vice-President, F. L. Tarleton; Secretary-Treasurer, Herman Baum. May 19. Attendance 26.

University of North Carolina

Superpower Systems, by C. Ted Smith,
Short Waves in Radio, by J. D. McConnell, and
Electro-Therapeutics, by Keith Grady. May 14.

Ohio Northern University

Three-Brush Generator, by J. Ring. May 13. Attendance 14.

Ohio State University

The Transmission of Pictures by Wire, by A. B. Clark, American Telephone and Telegraph Co. Illustrated. The following officers have been elected: President, LeRoy W. Hendershott; Vice-President, George W. Hoddy; Financial-Secretary, Fullerton S. Kinkead. May 20. Attendance 200.

Oklahoma University

Opportunities for the Young Engineer in Public Utilities, by F. C. Meyers, Oklahoma Gas and Electric Co. Motion pictures on the manufacture of X-ray tubes and storage batteries were shown. May 14. Attendance 35.

Oregon Agricultural College

Business Meeting. The following officers were elected: President, Harry E. Rhoades; Vice-President, Deskin O. Bergey; Secretary-Treasurer, Blair E. Plowman. May 21. Attendance 23.

Pennsylvania State College

Business Meeting. May 19. Attendance 25.

Business Meeting. The following officers were elected: President, W. L. Kochler; Vice-President, A. P. Jackel; Secretary, J. E. Hogan; Treasurer, Wm. Eglinton. May 28. Attendance 35.

University of Pennsylvania

Light and Color, by Arthur W. Goodspeed. May 15. Attendance 107.

University of Pittsburgh

Plant Management, by S. B. Williams, Bell Telephone Co. March 6. Attendance 50.

Electric Heating, by D. S. Templeton. March 13. Attendance 28.

History of Radio, by H. A. Thompson, and

Voice-Frequency Carrier-Wave Telegraphy, by G. R. Boardman. March 20. Attendance 25.

A motion picture, entitled "The Single Ridge," was shown. April 24. Attendance 30.

Synchronous Machinery for Tying Lines Together, by N. Watkins,

Testing Railway Motors, by F. McTaggart,

History of Electrical Railways, by H. Cramer, and

Lighting Installation in Hollywood, by J. G. Pattillo. May 8. Attendance 26.

Annual Banquet. Talks were given by D. P. Mitchell, A. L. Plette, and D. S. Templeton, students, and H. E. Dyche, F. L. Bishop and C. W. Ridinger. May 19. Attendance 43.

Purdue University

The Heritage of the Engineer, by Professor D. D. Ewing. The following officers were elected; Chairman, W. O. Osbon; Vice-Chairman, F. C. Yarling; Secretary, R. C. Parker; Treasurer, F. A. Johantges. May 12. Attendance 22.

Rensselaer Polytechnic Institute

Business Meeting. The following officers were elected: Chairman, F. M. Sebast; Secretary-Treasurer, Kenneth C. Wilsey. May 14. Attendance 26.

Rutgers University

Business Meeting. The following officers were elected: President, Stanley Hunt; Vice-President, E. Siddons; Secretary-Treasurer, Selden B. Aylsworth; Recording Secretary, William H. Bohlke. May 18. Attendance 20.

Rhode Island State College

The Singing and Talking Arc Lamp, by A. Ganz and E. A. Arnold, and

The Electrical Process of Forging Iron, by M. Norman and B. Taylor. Demonstrations illustrating each talk were made by the author. May 13. Attendance 18.

The Superpower Project of the North East Section of the United States, by E. Siswick. The following officers were elected: Chairman, D. B. Brown; Secretary, S. J. Bragg. May 27. Attendance 15.

South Dakota School of Mines

Business Meeting. The following officers were elected: Chairman, J. V. Walrod; Secretary-Treasurer, C. Allen. May 22. Attendance 9.

University of Southern California

History and Development of Mill Creek and Santa Ana Canyon Hydroelectric Power Plants, by E. R. Stauffacher, Southern California Edison Company, and

Automatic Switches and Protecting Devices, by E. R. Stauffacher. April 30. Attendance 22.

Inspection trips to several of the Mill Creek and Santa Ana Canyon Plants were made. May 1 and 2. Attendance 13.

The General Electric Company's Test Course, by Julian Summers and Robert Rowley. May 14. Attendance 32.

Stanford University

Business Meeting. The following officers were elected: Chairman, Fred E. Crever; Vice-Chairman, W. B. Wells; Secretary-Treasurer, Curtis R. Walling. June 2. Attendance 16.

University of Texas

Business Meeting. April 24. Attendance 8.

University of Utah

The Industrial Applications of Electricity, by John Salberg, Westinghouse Electric & Mfg. Co. May 26. Attendance 65.

University of Virginia

The Engineer after College, by N. J. Painter, Bartlett Haywood Co. The following officers were elected: Chairman, T. M. Linville; Secretary, H. M. Dixon; Treasurer, J. M. Roberts. May 21. Attendance 16.

Washington State College

The Advisability of Accepting a Position with a Large Company, by Professor Osborn. April 23. Attendance 25.

Business Meeting. The following officers were elected: President, D. D. Miller; Secretary, L. A. Traub; Treasurer, M. L. Cumming. May 26. Attendance 19.

Washington University

Inspection trip through the Wagner Electric Company's plant. The manufacturing of electrical equipment was inspected. May 1. Attendance 30.

Business Meeting. The following officers were elected: President, W. W. Braken; Vice-President, D. Meyers; Secretary, S. E. Newhouse, Jr., Treasurer, Clarence Loveless. May 14. Attendance 33.

West Virginia University

The Colfax Power Station of the Duquesne Light Company, by Mr. Henderson,

The Machine-Switching Station of the Bell Telephone Company, by Mr. Gramm,

Influence of Radio on Power Development, by Mr. Osborne,

Westinghouse Electric and Manufacturing Company, by Mr. Kisner, and

Manufacture of Built-Up Mica, and Other Insulation, by Mr. Jones. May 15. Attendance 24.

University of Wisconsin

Idealism and the Engineer, by Professor Jansky. May 27. Attendance 25.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES JUNE 1-30, 1925

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

APPLICATION OF HYPERBOLIC FUNCTIONS TO ELECTRICAL ENGINEERING PROBLEMS.

By A. E. Kennelly. 3rd edition. N. Y., McGraw-Hill Book Co., 1925. 352 pp., diagrs., tables, 9 x 6 in., cloth. $3.50.

The third edition of Dr. Kennelly's well-known textbook has been considerably revised. Parts of the original text have been replaced by new and more recent material, some corrections have been made and five new appendixes have been added. Among the important additions are an application of hyperbolic functions to electrical conducting networks and a theorem for the constant mean-to-mid ratio of potentials or current along a uniform line in the steady state.

ART OF TOWN PLANNING.

By Henry Vaughan Lanchester. N. Y., Charles Scribner's Sons, 1925. (Universal Art Series). 244 pp., illus., plans, 9 x 6 in., cloth. $7.50.

Mr. Lanchester discusses town planning as an art in which a knowledge of architecture, arboriculture, horticulture, hygiene, economics and allied subjects must be combined and utilized. Prevented by the limits of space from covering this wide field in detail, he has provided an outline of conditions in the past and at the present time, which traces the evolution of town planning and indicates the lines along which modern ideas are developing.

CHEMISTRY TO THE TIME OF DALTON.

By E. J. Holmyard. Lond., Oxford University Press, 1925. (Chapters in the history of science, v. 3). 128 pp., illus., ports., 7 x 5 in., cloth. $1.00. (Gift of Oxford University Press, American Branch).

In the brief compass of this book, Mr. Holmyard gives an interesting, intelligible account of the development of chemistry from the earliest times to the close of the eighteenth century. Attention is directed to ideas rather than to substances, the continuity of chemical thought has been emphasized, and the author tries to show that the theory of evolution is applicable to the development of science as well as to the living world.

LA COMPTABILITE MODERNE.

By J. Dumarchey. Paris, Gauthier-Villars et Cie, 1925. 372 pp., 10 x 6 in., paper. 40 fr.

The object set before him by the author of this work is the establishment of a rational system of accounting which will rest on a sound philosophic and scientific basis and also meet technical requirements. In his discussion, he has made extensive developments of various entirely new theories of accounting, he states. These theories are set forth at length and finally condensed into simple formulas that can be readily applied in practice.

CONCERNING THE NATURE OF THINGS.

By Sir William Bragg, N. Y., Harper & Bros., 1925. 250 pp., illus., 8 x 6 in., cloth. $3.00.

Contents: Atoms of which things are made.—Nature of gases.—Nature of liquids.—Nature of cystals; Diamond.—Nature of crystals; Ice and snow.—Nature of crystals; Metals.—Note.

In 1825 the Royal Institution instituted a series of Juvenile Lectures which have been given annually since that time by many famous men of science and have set a high standard as models of popular exposition. The present volume is an outgrowth of the course of lectures given by Sir William Bragg in 1923-24. It treats of the structure of the atom and of the molecular forms exhibited by matter in various states, bringing to the reader the most recent discoveries and modern views, and illustrating them with many novel experiments.

ECONOMICS OF OUR PATENT SYSTEM.

By Floyd L. Vaughan. N. Y., Macmillan Co., 1925. 288 pp., 8 x 5 in., cloth. $2.50.

The author says that the patent system has been bent to purposes and has facilitated results never intended or expected by the framers of the Constitution and the patent system. Patents have been used to defeat the object of the anti-trust laws, to restrain trade and to form industrial monopolies. They have been used as a pretext for unfair methods of competition and, to this end, many have been suppressed. Various evils have discouraged invention.

The social and economic cost of our patent system—industrial monopolies, suppression of patents, discouragement of invention, and economic waste—constitutes a tremendous liability in appraising its net utility. This cost is the subject of the greater part of this book. The final chapter suggests remedies for the situation.

ELECTRICAL-MACHINERY ERECTION.

By Terrell Croft, N. Y., McGraw-Hill Book Co., 1925. 314 pp., illus., diagrs., tables, 8 x 6 in., cloth. $3.00.

Deals with the mechanical features of installation, describing the methods used from the unloading of the apparatus from the car to its final placing and aligning in position for operation. The mechanical maintenance of electrical machinery is also described.

ELEMENTS OF RAILWAY ECONOMICS.

By Sir William M. Acworth. New ed. rev. & enl. Oxford, Clarendon Press, 1924. 216 pp., 7 x 5 in., cloth. $1.20. (Gift of Oxford University Press. American Branch).

This book was first published almost twenty years ago and has been reprinted several times. Until now, however, it has never been revised, and the form of the accounts and the statistics inserted to illustrate the economic argument were quite out of date. For these reasons the present revised edition has been prepared. In it, the text remains broadly unchanged, but the facts have been brought up to date and the illustrations taken from recent experience. Three new chapters have been added, dealing with passenger traffic and with the changes that occurred during and since the war. In its new form, the work meets the need for a text-book adapted to conditions in Great Britain.

FARM MOTORS.

By Andrey A. Potter. 3d edition, rev. & enl. N. Y., McGraw-Hill Book Co., 1925. (Agricultural engineering series). 299 pp., illus., diagrs., 9 x 6 in., cloth.

This textbook presents the fundamental principles that govern the construction, working and management of motors that are suitable for farm use. It is intended primarily for students of agricultural engineering but is arranged so that it can be used as a reference work by farmers and machine operators.

In this edition, the chapters on gas engines and on traction engines have been enlarged, and the other chapters revised.

FERNMELDELEITUNGEN BEIM ELEKTRISCHEN ZUGBETRIEB DER DEUTSCHEN REICHSBAHN.

By Otto Brauns u. Wilhelm Wechmann. Berlin, V. D. I. Verlag, 1925. 99 pp., diagrs., 8 x 6 in., paper. 6 mk.

In 1923 the German government arranged an inspection trip over an electrically operated railroad in Silesia by representatives of the electrical industry and of the bureaus in charge of railroads, telegraphs and telephones in Sweden, Norway, Austria, Switzerland and Germany. The question of inductive interference between alternating current railway circuits and low-tension circuits was discussed extensively by the party.

This book presents to a wider circle the papers read on that occasion, with the more important discussions.

FINANCIAL HISTORY OF THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY.

By J. Warren Stehman. Boston, Houghton Mifflin Co., 1925. 339 pp., 8 x 5 in., cloth. $2.50.

Traces the financial development of this great industry from its period of inception, in 1876, to the present time. In addition, the author discusses government regulation of the telephone industry and its effect on the Bell system, and also devotes a chapter to certain conditions or practises which his study has disclosed and which are important socially and financially.

HISTORY OF MATHEMATICS.

By David Eugene Smith. Boston & N. Y., Ginn & Co., 1923-1925. 2 v., illus., facsims., 9 x 6 in., cloth. v. 1, $4.00; v. 2, $4.40.

These two volumes contain a readable account of the development of elementary mathematics, through the first steps in calculus, from the earliest times down to the present. The story is illustrated with many portraits and with diagrams and pictures from old mathematical books. Ample bibliographical data are provided.

The work is planned to present the subject from two distinct standpoints. In volume one, the growth of mathematics is presented by chronological periods, with due consideration to racial achievements. In volume two, the evolution of certain important topics is described.

While intended primarily for teachers and students of mathematics, the book will undoubtedly interest many engineers and others who use mathematics.

MAN AND HIS AFFAIRS FROM THE ENGINEERING POINT OF VIEW.

By Walter N. Polakov. Baltimore, Williams & Wilkins Co., 1925. 233 pp., 8 x 5 in., cloth. $2.50.

The author advocates the use of the mathematical method in the study of man and his affairs. Heretofore, he says, man has either been outlawed from nature and speculated about in metaphysical and theological terms, or else the broad subject has been lost in a maze of psycho-physiological details. The new point of view of the universe, man included, makes him a part of nature, susceptible to scientific study without resort to metaphysics. The book is intended to present this new viewpoint to the general reader and to indicate some of the advantages that it promises.

HOUSEHOLD REFRIGERATION.

By H. B. Hull. Chicago, Nickerson & Collins Co., 1924. 328 pp., illus., tables, 9 x 6 in., cloth. $3.50.

A treatise covering methods of household refrigeration by ice and by refrigerating machines. The theory of refrigeration and the properties of the suitable refrigerants are set forth, heat transfer is discussed and there are descriptions of many types and constructions of refrigerating machines and refrigerators. Chapters are devoted to the operation of refrigerators, to testing methods and to the preservation of foods in the home. Many tables of numerical data used by engineers are included. This is the first book on this subject, the author says.

INTRODUCTION TO THE LITERATURE OF CHEMISTRY.

By F. A. Mason. Oxford, Clarendon Press, 1925. 41 pp., 7 x 5 in., paper. $.70. (Gift of Oxford University Press. American Branch).

A useful brief guide to engineers, chemists and patent attorneys who may at times have to search chemical literature. It describes the important books of reference in general chemistry and the major special branches, as well as the leading periodicals, and gives suggestions on the best methods for making searches.

MECHANICAL DESIGN OF OVERHEAD ELECTRICAL TRANSMISSION LINES.

By Edgar T. Painton. N. Y., Van Nostrand Co., 1925. 274 pp., illus., diagrs., tables, 9 x 6 in., cloth. $6.00.

This treatise, intended primarily for the designer and the consulting engineer, is planned to describe the latest constructional details and the present trend of thought on methods of design. Those features which experience has shown to be desirable are pointed put and the extent to which the limitations of commercial manufacture enable them to be realized is indicated. Attention is paid to the practical side of construction, as well as to theory, and one chapter is devoted to methods of erection.

MECHANICS OF MACHINERY; KINEMATICS AND DYNAMICS.

By Robert C. Heck. N. Y., McGraw-Hill Book Co., 1925. 550 pp., diagrs., tables, 9 x 6 in., cloth. $5.00.

This second volume of Professor Heck's textbook is devoted to the study of motions and forces within machines; with the previous volume on machine design, the work forms a fairly complete treatise on these important divisions of the scientific background of mechanical engineering. The book includes something on all important subdivisions of the subject and gives a consistent, correlated treatment of their various parts. It is arranged so that courses of varying length and content may be selected. Certain topics, such as the modern theory of lubrication, Stribeck's work on ball bearings and Barth's theory of belt action have not previously been put into textbook-shape, the author states.

NEW PRODUCTION METHODS IN VOLUMETRIC ANALYSIS.

By Edmund Knecht and Eva Hibbert. 2nd edition. Lond. & N. Y., Longmans, Green & Co., 1925. 134 pp., 9 x 6 in., cloth. $3.00.

Titanous chloride and titanous sulfate present several advantages over the reducing agents commonly enployed in volumetric analysis, and the present monograph is intended to call attention to their usefulness and to provide accurate methods for applying them practically. The methods included are for the determination of various metals and non-metallic compounds, for dyestuffs and sugars.

PERSONAL LEADERSHIP IN INDUSTRY.

By David R. Craig and W. W. Charters. N. Y., McGraw-Hill Book Co., 1925. 295 pp., 8 x 6 in., cloth. $2.50.

This book is concerned, not with the question of personnel administration, but with the important problem of the supervision of subordinates. It is intended to make available the experience of successful executives in handling this individual problem.

By a study of the methods used by successful executives, the authors have determined the qualities and traits of character involved in effective personal leadership in industry. These are defined and suggestions made to assist in developing them.

PHYSICO-CHEMICAL EVOLUTION.

By Ch. Eug. Guye. N. Y., E. P. Dutton & Co., n. d. 172 pp., 8 x 5 in., cloth. $2.40.

Contents: Einstein's principle of relativity in the classification of sciences.—Evolution of physico-chemical phenomena and the calculus of probabilities.—Carnot's principle and the physico-chemical evolution of living organisms.

These three papers, which have appeared in various journals during recent years, are more or less related to the same subject, the new conception of the physico-chemical evolution of a system which has arisen since the investigations of Gibbs and Boltzmann have called attention to the significance of Carnot's principle. The first paper attempts to show how the principle of relativity may constitute a first step towards the union of sciences which are metaphysically separated by the conditions on which they are founded. The second paper is intended to show the statistical importance of Carnot's principle. The last paper endeavors to show that this principle, considered as a statistical principle, must disappear when it is sought to apply it to living matter.

PORT DEVELOPMENT.

By Roy S. MacElwee. N. Y., McGraw-Hill Book Co., 1925. 456 pp., illus., maps, tables, 9 x 6 in., cloth. $5.00.

"Port Development" is concerned primarily with questions of government, administration, traffic and solicitation; in other words, with those problems other than mere physical terminal facilities, which are fundamental in the competitive ability of a port. In the first section, the author discusses the general value of port development to the nation and the port city, the effect of government laws, port administration and freight solicitation. Section two compares the statistics and physical features of many of the world's ports and discusses the advantages of location. The third section analyzes the comparative traffic advantages of ports, including rates, costs and services. The fourth section treats of free ports and their advantages in port development.

PREPARATION OF SCIENTIFIC AND TECHNICAL PAPERS.

By Sam F. Trelease and Emma S. Yule. Baltimore, Williams & Wilkins Co., 1925. 113 pp., 8 x 5 in., cloth. $1.50.

A manual of style for the assistance of those who are writing articles on scientific and technical subjects, theses, reports, etc. The book discusses such matters as the collection of data, arrangement of subject matter, preparation of manuscript, proof-reading, illustrations, etc. There is much practical infor-

mation on questions of grammar, style, footnotes, etc., all presented with conciseness and clearness. The book should be distinctly helpful to any writer.

PRODUCTION AND MEASUREMENT OF LOW PRESSURES.
By F. H. Newman. N. Y., D. Van Nostrand Co., 1925. 192 pp., diagrs., tables, 9 x 5 in., cloth. $5.00.

Although high vacuum technique occupies an important position in engineering and physics today, it has been difficult to obtain information on the subject, because the data are scattered in many publications. The present volume is intended to lessen the difficulties of workers in this field by providing an account of the more important instruments and devices used in high vacuum work.

After an introductory chapter, the varieties of pumps,—oil, mercury, high-speed molecular and mercury vapor—are described in detail. Other processes for removing gases—by sorption, chemical, thermal and electrical—are discussed. There are chapters on manometers and on procedure in exhausting vessels and appendices of useful data concerning vapor pressures, pump speeds, etc.

PSYCHOLOGY OF SELECTING MEN.
By Donald A. Laird. N. Y., McGraw-Hill Book Co., 1925. 274 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

The purpose of this book is to set forth, in a non-technical way, a technical account of the fundamental considerations in selecting men. The author first surveys critically traditional methods of selection, by letters of application, photographs, interviews, recommendations, etc. From these he proceeds to a description of the scientific method of selection and to a formulation of the principles to be followed by employees in the use of this method. Dr. Colgate is Associate Professor of Psychology at Colgate University.

DER QUECKSILBERDAMPF-GLEICHRICHTER, vol. 1; Theoretische Grundlagen.
Berlin, Julius Springer, 1925. 217 pp., 9 x 6 in., boards. 5.-gm.

The theoretical section of a two-volume work on the mercury-vapor rectifier. It is based on a series of investigations by the author and on examination of the literature, from which a coherent exposition of rectifier theory has been evolved. Five pages of bibliographic references are included.

RESISTANCE OF MATERIALS.
By Fred B. Seely. N. Y., John Wiley & Sons, 1925. 442 pp., diagrs., tables, 9 x 6 in., cloth. $3.75.

The author of this textbook is Professor of Theoretical and Applied Mechanics at the University of Illinois, and the book, it may be assumed, represents the general course given at that school. The first, and longer, part of the work dealing with the Mechanics of materials, treats chiefly of the application of the principles of Analytical Mechanics and of the experimental laws of structural materials to the analysis of the members used in structures and machines. The second part treats of the force-resisting properties of engineering materials. In part one, rational methods are developed for the design of the common types of force-resisting members used in engineering structures. Part two investigates those properties of materials from which the suitability of the material for various structural uses may be determined and considers the tests that will measure these properties.

RIGID AIRSHIP; a Treatise on the Design and Performance.
By E. H. Lewitt. Lond. & N. Y., Isaac Pitman & Sons, 1925. 283 pp., illus., plates, diagrs., 9 x 6 in., cloth. $8.50.

The first complete work on the subject, the author asserts, to be published in the English language. The author writes on the basis of personal experience and intends the work for designers and students of aeronautics with good engineering training. The field is restricted to structual design and performance; engines and machinery are not discussed.

STRENGTH OF MATERIALS.
By Edward R. Maurer and Morton O. Withey. N. Y., John Wiley & Sons, 1925. 382 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.50.

Intended primarily as a textbook for the authors' students in the University of Wisconsin, this book covers the ground usually included in undergraduate courses. The authors have aimed at a teachable book. Particular attention has been given to definitions, demonstrations, proofs, solved illustrative examples and problems.

ZSIGMONDY FESTSCHRIFT; JUBELBAND DER KOLLOID-ZEITSCHRIFT . . . . . hereausgegeben von W. Bachmann und Wo. Ostwald. Dresden Theodor Steinkopff, 1925. 390 pp., illus., port., tables, 10 x 8 in., paper. 20.-gm.

To commemorate the sixtieth birthday of Richard Zsigmondy, the pioneer investigator of colloids, his friends and former pupils have published this attractive volume. In it are published some forty articles describing recent research in various fields of colloidal chemistry, contributed by well-known chemists, European and American. Certain of these are of interest to metallurgists and geologists, others to investigators of rubber, cellulose products and lubrication.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE. Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

MEN AVAILABLE

MECHANICAL AND ELECTRICAL DESIGNER AND DRAFTSMAN, age 29, single, thoroughly accurate in electrical and mechanical design of motors and transformers, also lifting machines and structural steel work. Developing new designs for pumps, etc., specializing in vacuum pumps for mercury arc rectifiers. Research work in field of electric furnaces suitable for foundry. B-9708.

ASSISTANT EXECUTIVE, technical graduate, age 33, married, desires connection with progressive company in commercial capacity, or industrial engineering firm. Work has covered manufacturing, time studies, plant layout, distribution systems, costs, sales, advertising and statistical studies of expenses, revenues and other administrative problems. Location, New York, New England. Available reasonable notice. B-9122.

ASSISTANT DISTRIBUTION ENGINEER, age 31, single, technical graduate, desires position in engineering department of a large public utility or engineering firm located in the middle West. Five and a half years with the overhead distribution department of a public utility. Salary secondary consideration. B-9891.

ELECTRICAL ENGINEER, age 33, married, technical graduate with ten years of practical experience on factory test course, construction and

office engineering. Now employed. Prefers general engineering work with opportunity to work into worthwhile position. Location desired in middle West. B-9936.

ELECTRICAL ENGINEER, Swedish University graduate, excellent physique, four years good general experience in drafting, design, operation and maintenance of power plants. Desires a position abroad in South America, India, Cuba or West Indies. B-9953.

ELECTRICAL ENGINEER, age 26, married, technical graduate, Westinghouse graduate student, Supply Sales Engineering Course, desires a position as sales engineer with electrical manufacturing company. Location, West. B-9951.

RATE ENGINEER, technical graduate, age 31, with executive ability. Broad experience in the gas and electric utility business on rates, power sales, engineering and operation. Desires connection with holding or management company of public utilities or with power company. Available on reasonable notice. B-9782.

UNIVERSITY GRADUATE, age 28, one and one-half years electrical shop construction and maintenance experience, one year with one of largest power distributors at transmission line survey, location, inspection, office drafting. Desires permanent position at transmission line substation drafting, design. Preferably North Central States or Eastern Canada. $135 per month with opportunity. Available one month. B-9556.

CONSULTING ENGINEER, technical graduate, fifteen years' experience, at present in private practise, will consider suitable connection with public utility or industrial plant. Ten years' experience design, construction and operation of high tension transmission systems. A-2191.

ENGINEER-SCIENTIST, age 30, married, educated at M. I. T., three years in chemistry, three years in mathematical physics, graduating in mechanical engineering. Employed as technical report writer for research laboratory of G. E. and as industrial physicist and designer by Corning Glass Works. Executive experience and broad training in commercial subjects. Employed. B-9930.

ELECTRICAL ENGINEERING GRADUATE, 1922, age 28, married, two and one-half years' experience in railway signaling, one year in electric traction on maintenance of equipment, desires position with railway or public utilities company. Available on reasonable notice. B-9961.

INSTRUCTOR, electricity or physics, age 36, married, B. S., 1913, E. E., 1918, eight years practical experience, six years successful teaching D. C. and A. C. theory and laboratory. Minimum salary $3500 a year. B-9880.

ELECTRICAL ENGINEER, technical graduate, single, age 30, five and one-half years' experience on design of electrical heating devices, also experience in design of heating and motor control devices. Connection with a growing, reliable concern desired. Location preferred, Northeast. Available immediately. B-9981.

ELECTRICAL ENGINEERING INSTRUCTOR in a university of high rank desires a change; age 30, married. Seven years and five summers of engineering and teaching experience. Especially qualified for circuits and communications engineering. Will consider either a teaching or an industrial position. C-3.

ELECTRICAL ENGINEERING GRADUATE, age 26, single, having had two years G. E. Test and office work, desires position with public utility or manufacturing company. Available on short notice. B-8365.

ELECTRICAL ENGINEER, age 26, experience electrical testing in charge of electrical testing apparatus, and chief draftsman. Desires position designing, developing electrical apparatus or machinery, or assistant to superintendent of factory manufacturing such apparatus or machinery. Inventive, energetic, tactful, best references. Available on month's notice. Salary $2500. New York location preferred, but not essential. B-7270.

ELECTRICAL ENGINEER, who wishes to continue studies in Chicago, would like position where his evenings will be free. Preferably meter and test department. Ten years' experience. B-9992.

ELECTRICAL ENGINEER, age 25, single, B. S. in E. E., M. S. in Physics and mathematics, three years' experience teaching college physics; experience electrician, power plant operator, building construction. Research and special training in field of thermo-electricity and thermo and galvano-magnetic effects. Prefer position research department of college, or company interested in thermo-electricity. Location immaterial. C-23.

ELECTRICAL ENGINEER, finishing two year contract in charge of electrical construction with large Eastern manufacturing concern, desires connection in similar capacity. Familiar with installation and operation of most types of electrical equipment, power plant design, and industrial lighting. Would consider combined maintenance and construction work. Interview if desired. References. C-38.

OPERATING ELECTRICAL SUPERINTENDENT OR DEPARTMENTAL HEAD, graduate of a leading engineering college, with long and practical experience in charge of generation, (by hydraulic and steam plants) transmission and distribution for both public utility, railway and isolated power plants, including applications of electricity to various industrial uses. B-3618.

ELECTRICAL ENGINEERING GRADUATE, 1924, desires permanent position in the electrical department of a manufacturing concern or power plant. For past year employed by a large New Jersey utility corporation testing power plant equipment and computing test results. Available on short notice. Location preferred, New York City. B-8265.

ELECTRICAL-MECHANICAL ENGINEER, wide experience installation, operation, rehabilitation of hydroelectric plants, steam power plants, superintendence mechanical, electrical departments large mining and milling units. Seeks connection with industrial enterprise with view to managing electrical and mechanical department as chief engineer, electrical or mechanical superintendent. Excellent references. Prefers Middle-west or Southwest. Employed. Available thirty days. B-3699.

ELECTRICAL ENGINEERING GRADUATE, married, B. S. degree, nine years with a large corporation, wide experience in testing electrical machinery of all kinds, meter expert, designing engineer. Desires Western location, preferably a laboratory position in an engineering school. Available on thirty days' notice. C-50.

OPERATING ENGINEER-GENERAL SUPERINTENDENT OR MANAGER, desires to be placed in touch with utility property, either electric or gas, or combined, 25,000 customers or upward. Preferably North Middle Central States or Canada. Twenty-one years active contact with operating problems in electric, gas, water and telephone utility service, as cadet engineer, superintendent of distribution, chief engineer, general superintendent, manager. Employed. C-44.

ELECTRICAL ENGINEER, technical graduate, eighteen years' experience in charge of design, construction and operation, largely industrial, desires position as chief electrician or assistant electrical engineer in industrial plant, or industrial engineer with utility. Wide experience on motor applications, also on power plant and substation work. Ability to organize and train electrical department for industry. Available at once. B-715.

YOUNG MAN, age 25 married, desires permanent position with chance for advancement in engineering work. Have had three years university training in electrical engineering and four years' experience as test engineer with public utility concern, also experienced in radio and telephone work. C-29.

COLLEGE GRADUATE, age 35, fourteen years' experience designing and inspecting marine electrical equipment, desires position as sales representative. C-28.

ELECTRICAL ENGINEER, technical graduate, age 32, hydro stations operator, Westinghouse test and construction, domestic electric refrigeration salesman, contractors engineer with Chicago electrical contractor. Desires a position of responsibility. Prefer Chicago or West, but will go elsewhere. Must be permanent. C-45.

GRADUATE ELECTRICAL ENGINEER, 1923, age 25, married, fifteen months' experience in student engineering with the General Electric Company and nine months' experience as instructor in electrical engineering. West preferred. C-54.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING desires change. Has had seven years of teaching experience in mathematics and electrical engineering, one and one-half years in the testing department, or in the engineering laboratory of the General Electric Company. Position in the East or Middlewest is preferred. Available in September. C-56.

ELECTRICAL ENGINEER, technical graduate from recognized university; young, healthy, dependable; mathematician, inventor, works efficiently. Fourteen months public utilities, three and one-half years in electrical and radio research, test, designing, manufacturing, production supervisor. Desires connection with public utility, electrical or radio concern recognizing ability. Compensation secondary importance. Available on short notice. B-7178.

ELECTRICAL ENGINEER, versed also in mechanical, structural steel, concrete work, power stations, transmission, etc.; design, construction, operation; practical, theoretical, reliable, responsible service. B-7337.

ENGINEER-EXECUTIVE, electrical, industrial or constructional; B. S. degree E. E. 1915, 32, married. Experience; two years graduate apprentice work Westinghouse Electric and Manufacturing Company, two years officer U. S. Army, five years plant engineer covering time study, rate setting efficiency and production work, one year substation construction work. Employed, available reasonable notice. B-9436.

ELECTRICAL-ENGINEER, 26, graduate of engineering college, G. E. student engineering course, two years' experience with public utilities; experienced turbine man. At present employed as engineer of sugar company in tropics. Would like to obtain similar position with industrial company in the States. Available one month. Location immaterial. B-9833.

EXECUTIVE-ENGINEER wants position with great responsibility. Designed, constructed and operated some of the largest steam and hydraulic power plants, including transmission lines of every size; well versed in contracts and rates. Unprofitable plants have been converted into very successful enterprises. Can produce results. A-1 references. Available on short notice. B-8069.

GRADUATE MECHANICAL ENGINEER, age 30, married, six years machine shop, designing and production engineering on automatic book-binding and printing machinery, two years on manufacture of electric motors, two years works engineer manufacturing brass, bronze and nickel hardware. Desires responsible position in plant or field. Available on short notice. C-43.

ELECTRICAL ENGINEER, 27, B. S. graduate. At present factory sales and service representative for nationally known storage battery company. Wide practical service experience, especially automotive and telephone; three years broad experience in successfully developing own business. Desires engineering proposition, preferably sales and service where real effort and executive ability have opportunity. New Hudson Coach available for business. C-75.

GRADUATE ENGINEER, B. S. in E. E. 1925, age 34, single, speaks Greek. Wants something permanent and with a future for hard worker. Will go anywhere in United States. Now available. C-85.

ELECTRICAL ENGINEER, B. S. in E. E. 1921, age 28, single, two years operation and maintenance in large power plant, high tension engineering, one year electrical repair shop instructor, nine months rehabilitation assistant. Can handle men. B-8444.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED JUNE 25, 1925

AMBELANG, CARL ELDER, Engg. Dept., Public Service Co. of Northern Illinois, Chicago, Ill.
ANDERSON, EDWIN CARL, Asst. Radio Engineer, Ware Radio Corp., 429 W. 42nd St., New York; res., Lynbrook, N. Y.
ASCHEMEYER, ELMER, Watch Electrician, Cohokia Station, Union Electric Light & Power Co., East St. Louis, Ill.; res., St. Louis, Mo.
ATHERTON, ALBERT, Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.
ATWOOD, HOMER S., Sales Manager, Northeastern District, Puget Sound Power & Light Co., Everett, Wash.
BADCOCK, WILLIAM, Asst. Supt., British Columbia Electric Railway Co., Lake Buntzen, Burrard Inlet, B. C., Can.
BALLOCK, RALPH HARRY, Electrical Engineer, Light & Water Dept., City of Tacoma, Tacoma, Wash.
BAPOOJI, EARUCHSHAW JEEJIBHOY, Electrical & Mechanical Engineer, The Shahabad Cement Co., Ltd., Shahabad, Nizam's State, India.
BARNES, EARL C., Substation Dept., Chicago, Milwaukee & St. Paul Railway, Hyak, Wash.
BARY, CONSTANTINE, Asst. Electrical Designer, Philadelphia Electric Co., 1035 Chestnut St., Philadelphia; res., Germantown, Pa.
BEARDSLEY, EARL H., Relay Maintenance, Cleveland Electric Illuminating Co., 75 Public Square, Cleveland, Ohio.
BAYLY, BENJAMIN DE FOREST, Student-at-Law, 108 Scott Block, Moose Jaw, Sask., Can.
BELL, JOHN BIRT, Meter Expert, Service Dept., General Electric Co., 1223 Washington Ave., Philadelphia, Pa.
BLAGOVESCHENSKY, LEO N., Engineering Assistant, Elec. Engg. Dept., Brooklyn Edison Co., Pearl St., Brooklyn, N. Y.
BLAIR, BERT ROY, Test Methods Engineer, Western Electric Co., Inc., 268 W. 36th St., New York; res., Jackson Heights, N. Y.
BLUME, NORMAN HAROLD, Transmission Supervisor, Wisconsin Telephone Co., 16 Carroll St., Madison, Wis.
BODEKER, CHARLES CARROLL, Valuation Engineer, Murrie & Co., 45 E. 17th St., New York, N. Y.
BOLLINGER, CHARLES HENRY, Appraisal & Inventory Work, Murrie & Co., Inc., 52 Broadway, New York, N. Y.
BOOTES, HENRY VAN DYKE, Valuation Engineer, J. L. Murrie & Co., 45 E. 17th St., New York, N. Y.
BOOTH, FRANK WHITEHEAD, Electrical Designing Engineer, Toronto Hydro-Electric System, Toronto, Ont., Can.
*BOUILLON, LINCOLN, Drafstman, Stone & Webster, Inc., Holland Bldg., Seattle, Wash.
BOURKE, ARTHUR MURDOCH, Asst. Engineer, Dist. "S," Public Service Co. of Northern Illinois, Streator, Ill.
BOYD, GEORGE McADORY, Dist. Illuminating Engineer, Westinghouse Elec. & Mfg. Co., 3451 E. Marginal Way, Seattle, Wash.
BOYNTON, EDWARD J., Valuation Engineer, Murrie & Co., 45 E. 17th St., New York, N. Y.
BRADFORD, LEROY, Owner, Bradford Armature Works, 315 Broadway, East St. Louis, Ill.
BRAY, MARGUERITE MONA, Clerk, Pacific Portland Cement Co., Cement, Calif.
BRICKETT, JOHN EDWARD, Automobile Mechanic, Central Fire Hall, Moose Jaw, Sask., Can.
BRIEGER, ALADAR, Draftsman, New York Edison Co., 140th St. & Rider Ave., New York, N. Y.
BRISBOIS, ELDEN, Electrician, Motor Dept., Borroughs Adding Machine Co., Detroit, Mich.
BROKENSHIRE, W. S., Jr., Asst. to Distribution Engineer, Pennsylvania Power & Light Co., 802 Hamilton St., Allentown, Pa.
BROWN, J. EDWARD, Salesman, Westinghouse Elec. & Mfg. Co., 420 So. San Pedro St., Los Angeles, Calif.
BROWN, JAMES W., Designing Engineer, Chandeysson Electric Co., 4092 Bingham Ave., St. Louis, Mo.
BROWN, LAUREL HERMAN, Laboratory Supervisor, Western Electric Co., Inc., Chicago, Ill.
BROWN, LEONARD F., Electrical Dept., Los Angeles Railway Corp., 717 E. 16th St., Los Angeles, Calif.
BROWNELL, F. W., Comptroller, Puget Sound Power & Light Co., 201 Electric Bldg., Seattle, Wash.
BUCKINGHAM, EARL WILLOUGHBY, Valuation Engineer, Murrie & Co., Inc., 37 E. 17th St., New York; res., Brooklyn, N. Y.
BUCKLEY, HAROLD P., Inspector, Murrie & Co., 47 E. 17th St., New York; res., Brooklyn, N. Y.
BURCHETT, CHARLES REGINALD, Electrical Inspector, New York Rapid Transit Corp. 85 Clinton St., Brooklyn; res., New York, N. Y.
BURKE, GEORGE ELLIS, Dist. Superintendent, Public Service Electric & Gas Co., 40 Columbia Ave., Passaic, N. J.
*BURKE, JAMES HARRY, Electrical Engeneer, Scranton Electric Co., Board of Trade Bldg., Scranton, Pa.
BURLEIGH, JOHN AGNEW, Supervisor, Transmission Maintenance, Pacific Tel. & Tel. Co., 506 Telephone Bldg., Seattle, Wash.
BURNETT, HENRY DARLING, Manager, Lighting Service Dept., Canadian General Electric Co., Ltd., 212 King St., W., Toronto Ont., Can.
BUSSARD, E. J. H., Engineer, The Crosley Radio Corp., 3401 Colerain Ave., Cincinnati, Ohio.
CALLAHAN, RAYMOND GERALD, Testing Engineer, Chicago Surface Lines, 231 S LaSalle St., Chicago, Ill.
CAMPBELL, HARLAN R., Telephone Inspector, Seneca Div., Lehigh Valley Railroad Co., Sayre; res., Athens, Pa.
*CANARY, JOHN F., Chief Electrician, New Amsterdam Gas Co., 20 Webster Ave., Long Island City; res., Astoria, N. Y.
*CARLTON, FRANK HENRY, Industrial Dept., General Electric Co., Schenectady, N. Y.
CARROON, WILLIAM EVAN, Jr., Asst. Professor, Elec. Engg. Dept., New Mexico State College, State College, New Mex.
CARTER, C. L., Local Manager, Virginia-Western Power Co., Main & Ridge Sts., Charlottesville, Va.
CARTER, HERBERT HILDER, Asst. Inspector, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.
CHARTIER, HAROLD SLOCUM, Engineer, Fulton County Gas & Electric Co., Gloversville, N. Y.
*CHILCOTT, EDWARD R., Junior Electrical Engineer, Bureau of Power & Light, City of Los Angeles, 120 E. 4th St., Los Angeles, Calif.
CHRISTENSON, RAY H., Electrician, Cleveland Electric Illuminating Co., 1528 E. 120th St., Cleveland, Ohio.
*CHUTE, GEORGE M., Jr., Industrial Engineering Dept., General Electric Co., Schenectady; res., Scotia, N. Y.
CLARK, ASTON AUBREY MATTHEW, Switchboard Operator, British Columbia Electric Railway Co., Stave Falls, B. C., Can.
*CLARK, CHESTER NICHOLAS, Substation Engineer, Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.
*CLARK, FRANKLIN PROCTOR, Sales Engineer, Wagner Electric Corp., 6400 Plymouth Ave., St. Louis, Mo.
CLARK, HARRY R., Radio Development, Engg. Dept., Eisemann Magneto Corp., 32-33rd St., Brooklyn, N. Y.
CLARK, ROBERT W., Sales Manager, Central District, Puget Sound Power & Light Co., Electric Bldg., 7th & Olive Sts., Seattle, Wash.
*COFFIN, DAVID DOUW, Student Engineer, Trans. Engg. Dept., General Electric Co., Pittsfield, Mass.
COHN, MARTIN, Electrical & Radio Engineer, Northway Radio Co., 1091 Southern Blvd., Bronx, New York, N. Y.
COLE, FRANKLIN ALBERT, Maintenance Engineer, New York Telephone Co., 309 Washington St., Newark, N. J.
CONCHA-GOUBERT, ADOLFO, Tester, Transformer Dept., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
COOPER, CLIFFORD W., Station Electrician, Public Service Co. of Northern Illinois, Waukegan, Ill.
COOPER, FRED E., Asst. Chief Electrician, Virginia Railway Co., Norfolk, Va.
COPELAND, J. B., Consulting Engineer, J. B. Copeland & Co., Apartado 1058, San Jose, Costa Rica.
*COVEY, ARNOLD BURTON, Transmission Engineer, Southwestern Bell Telephone Co., 1150 Boatmen's Bank Bldg., St. Louis, Mo.
COWARD, ARNOLD B., Office Engineer, Light & Power Dept., Cor. Broad St. & Dewdney Ave., Regina, Sask., Can.
COWLEY, JOHN ROBERTSON, City Electrical Engineer, City of Saskatoon, City Hall, Saskatoon, Sask., Can.
COYLE, HARRY SCUDDER, Asst. Director of Instruction, Ohio Bell Telephone Co., 4300 Euclid Ave., Cleveland, Ohio.
CROOKE, ROSCOE ROY, Factory Superintendent, NePage McKenny Co., Armour Bldg., Seattle, Wash.
CROPPER, ROLAND EDWARD, Clerk, Dist. Engineers Office, Service Dept., Canadian Westinghouse Co., Ltd., 366 Adelaide St., W., Toronto, Ont., Can.
CROWDER, H. G. Y., Draughtsman, Electrical Dept., British Columbia Electric Railway Co., Ltd., Vancouver, B. C., Can.
CURTIS, HENRY H., Treasurer, C. & P. Electric Works, Inc., 92 Hayden St., Springfield, Mass.
DAS, AMARENDRA CHANDRA, Chief Electrical Engineer In Charge, The Rajkot State Electric Supply Co., Rajkot, Kathiawar, India.
DAVIES, MEIRION, Electrical Estimator, C. H. E. Williams Co., Ltd., 509 Richards St., Vancouver, B. C., Can.
DAVIES, PHILIP M., Transmission Engineer, Southern California Telephone Co., 433 S. Olive St., Los Angeles, Calif.
DAVENPORT, ARTHUR EGBERT, Elec. Engg. Cadet, Public Works Dept., Hamilton, New Zealand.
DAVIS, HOWARD S., Asst. Engineer, Elec. Engg. Dept., Public Service Production Co., 80 Park Place, Newark, N. J.
DAVIS, JULIEN H., Power Salesman, Bureau of Power & Light, Los Angeles, Calif.

DEARDORFF, JOHN H., Maintenance of Test Equipment, Western Electric Co., Inc., Cicero; for mail, Chicago, Ill.

DEITRICH, EARLE E., Switchboard Wireman & Electrician, C. B. Hawley & Co., Camp No. 2, Oakland, Md.

DE KONING, THEODORE, Asst. Station Tester, Brooklyn Edison Co., Rockwell Place, Brooklyn, N. Y.; res., East Orange, N. J.

DETHRIDGE, STANLEY GEORGE, Chief Engineer, City Municipal Electric Light Plant, Power House, Winnipeg & Douglas Aves., Regina, Sask., Can.

DEUTSCH, ROBERT, Student, Pratt Institute of Technology, Brooklyn; res., New York, N. Y.

DEYOUNG, LOUIS WILLIAM, Proprietor, The Electric, 1127 E. Redondo Blvd., Inglewood, Calif.

DICK, WILLIAM, Superintendent of Inspection, Puget Sound Power & Light Co., Seattle, Wash.

DIPPEL, FREDERICK WILLIAM, Protection Div., Plant Engg. Dept., Wisconsin Telephone Co., 418 Broadway, Milwaukee, Wis.

DOUTHWAITE, KINGSLEY, Puget Sound Power & Light Co., Snoqualmie, Wash.

DRINKHOUSE, WILLIAM H., Draughtsman-Designer, The Cutter Electrical & Mfg. Co., 501 N. 19th St., Philadelphia, Pa.

DRUSCHKY, R. F., Sales Engineer, 3029 Locust St., St. Louis, Mo.

DRYAR, HENRY ALOYSIUS, Asst. Chief Load Dispatcher, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

DUNDATSCHECK, LOUIS, Chief Switchman, Hanover Central Office, New York Telephone Co., 104 Broad St., New York, N. Y.

*EADEN, NEAL, Engineer, Pacific Tel. & Tel. Co., 506 Telephone Bldg., 1200 3rd Ave., Seattle, Wash.

EGING, HENRY B., Asst. to Motor Engineer, The Electric Controller & Mfg. Co., 2700 E. 79th St., Cleveland, Ohio.

EICHER, HOMER LEROY, Sales Engineer, Eicher & Bratt, 570 Colman Bldg., Seattle, Wash.

ELLSWORTH, PAUL R., Asst. General Line Foreman, Cleveland Electric Illuminating Co., Public Sq., Cleveland, Ohio.

ENGLE, KARL DAVID, Foreman, Dubilier Condenser & Radio Corp., 43-51 W. 4th St., New York, N. Y.

EUSTACE, MARY M., Engineering Assistant, Western Union Telegraph Co., 195 Broadway, New York, N. Y.

FAIRMAN, FRANCIS EVARTS, Jr., Test Dept., Penna. Water & Power Co., Baltimore; res., Annapolis, Md.

FARMER, WALTER M., Asst. Engineer, Electric Bond & Share Co., 65 Broadway, New York, N. Y.; res., East Orange, N. J.

FARRELL, JOSEPH RICHARD, Commercial Engineer, General Electric Co., Witherspoon Bldg., Philadelphia, Pa.

FAULKNER, CARL FRANK, Fieldman, Transmission Dept., Southern Calif. Telephone Co., 433 S. Olive St., Los Angeles; res., Glendale, Calif.

FELLER, WILLIAM J., Electrical Maintenance, Hub Engineering Corp., 352 W. 50th St., New York; res., Lindenhurst, N. Y.

FERNANDEZ, GUILLERMO, Sales Engineer, General Electric Co., S. A., Apartado 403, Mexico, D. F., Mex.

*FERGUSON, FLOYD F., Manager, DX Radio-Lectric Co., 1303 Hertel Ave., Buffalo, N. Y.

FINLAW, JOHN, Load Dispatcher, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

FINN, JOSEPH ANTHONY, Electrician, Public Service Production Co., Edison Station, Paterson; res., Passaic, N. J.

FIRTH, BEN HANTON, Student, Pratt Institute, Brooklyn; res., Schenectady, N. Y.

FITZGERALD, FRANK GABRIEL, Tester, Western Electric Co., Inc., 112-118 W. 20th St., New York; res., Brooklyn, N. Y.

*FORD, ASA HERBERT, Engineer, Western Public Service Co., 8 E. Curtiss St., Downers Grove, Ill.

FORKNER, EARL ANDREW, Assistant to Sales Manager, Wagner Electric Co., 6400 Plymouth Ave., St. Louis, Mo.

FORSBERG, ELMER JOHN, Asst. Overhead Distribution Engineer, St. Paul Gas & Electric Co., St. Paul; res., Minneapolis, Minn.

FORSTER, ROBERT, Telephone Engineer, The New York Telephone Co., 104 Broad St., New York, N. Y.

FUJINO, SHIGEWO, Head of Kikuchigara Power Stations, Kumamoto Electric Co., Kumamoto, Japan.

GAMBLE, ROBERT E., Electrician, Preston & Bishop, Inc., 237 Maple St., Holyoke, Mass.

GARCIA, SIXTO EDMUNDO, Chief Electrician, Phoenix Utility Co., Electric Light Plant, Cardenas, Cuba.

GARMS, PETER, Superintendent, General Service Dept., Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.

GEORGE, ROBERT, Quotation Dept., General Electric Co., 1321 Walnut St., Philadelphia, Pa.

GILBERT, HENRY PEAKE, Asst. Engineer, Western Union Telegraph Co., 195 Broadway, New York, N. Y.

GLOVER, FRANK MILES, Electrical Inspector, New York Central R. R. Co., 466 Lexington Ave., New York, N. Y.

GRANT, LESLIE ROY, Asst. Sales Manager, Puget Sound Power & Light Co., 7th & Olive Sts., Seattle, Wash.

GREER, SINTON, Operator, British Columbia Electric Railway Co., Stave Falls, B. C., Can.

GUSTAFSON, CHARLES JULIAN, Methods Engineer, Western Electric Co., Inc., 268 W. 36th St., New York, N. Y.

*GUSTAFSON, CLIFFORD WALTER, Engineer, Mutual Fire Prevention Bureau, 230 E. Ohio St., Chicago, Ill.

HAEVERS, WILLIAM, District Engineer, Public Service Co. of Northern Illinois, Lacon, Ill.

HAGUE, JAMES H., Foreman, Test Dept., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.

HANLEY, JOHN FRANCIS, Technical Assistant, Electrical Testing Laboratories, 80th St. & East End Ave., New York, N. Y.

HANNAFORD, EARLE SHERMAN, Instructor, Elec. Engg. Dept., Georgia School of Technology, Atlanta, Ga.

HANSEN, HOLGER HILMER, Chief Engineer, Compania Azucarera El Ejemplo, Central El Ejemplo, Humacao Porto Rico.

HARMON, JAMES J., Equipment Engineer, Southwestern Bell Telephone Co., Boatmen's Bank Bldg., St. Louis, Mo.

HARRINGTON, ERNEST CLIFFORD, Meter Engineer, Staten Island Edison Corp., Richmond Terrace, Livingston; res., West Brighton, S. I., N. Y.

HARRINGTON, MICHAEL J., Asst. Foreman, Motor Division, Burroughs Adding Machine Co., Detroit, Mich.

*HART, WILLIAM COLERIDGE, Electrical Contractor, "The Shrubbery," Collymore Rock, St. Michael, Barbadoes, B. W. I.

HARVEY, ALFRED LEWIS, Distribution Engineer, E. W. Clarke Engineering Corp., Tennessee Power Bldg., Chattanooga, Tenn.

HAWE, JOHN ELDON, Electrical Designer, Stone & Webster, Inc., Electric Bldg., Seattle, Wash.

HEIMBURGER, HERBERT A., Sales Engineer, The Wagner Electric Corp., 19 Hiawatha St., Springfield, Mass.

HEMETER, LESLIE HALL, Sub-Foreman, Western Electric Co., Inc., New York, N. Y.

HERMAN, JOSEPH M., Test Engineer, Freed-Eisemann Radio Corp., 40 Flatbush Ave., Ext., Brooklyn; res., Brighton Beach, Coney Island, N. Y.

HERRMAN, CHARLES S., Jr., Evening Maintenance Force, New York Telephone Co., 227 East 30th St., New York, N. Y.

HILLIARD, CHARLES WESLEY, Asst. Engineer, United Electric Light & Power Co., 56 Cooper Sq., New York, N. Y.; res., Jersey City, N. J.

HOFFMAN, EDMOND L., Telephone Engineer, Southwestern Bell Telephone Co., Boatmen's Bank Bldg., St. Louis, Mo.

HOLT, EMERY FORD, Manager, Transelectric Co., 360 N. Michigan Ave., Chicago, Ill.

HOOD, GEORGE DOANE, Superintendent Telegraph & Telephone, Rock Island Lines System, Room 916, La Salle St. Station, Chicago, Ill.

HOOPER, ALBERT WALTER, Engineer In Charge of CKCK Station, Leader Publishing Co., Ltd., Regina, Sask., Can.

HOPEWOOD, PAUL, Inspector, Murrie & Co., Inc., 45 E. 17th St., New York, N. Y.

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HUSSEY, ROWLAND M., Electrical Department Superintendent, Jones & Laughlin Steel Corp., Woodlawn, Pa.
LOVETT, I. H., Associate Professor of Electrical Engineering, University of Missouri, Rolla, Mo.
MacTAVISH, HERBERT JAMES, Secretary, Toronto Electric Commissioners, Toronto, Ont.
MACY, RALPH G., Chief Engineer, Socony Burner Corp., Brooklyn, N. Y.
MERRILL, WARREN C., Engineer, Pacific Tel. & Tel. Co., San Francisco, Calif.
OTTEN, HENRY, Jr., Assistant Engineer, Economics, Interborough Rapid Transit Co., New York, N. Y.
OWEN, HARRY, Superintendent, Electrical Department, Truxillo Railroad Co., Puerto Castilla, Honduras, C. A.
PALME, ARTHUR, Electrical Engineer, General Electric Co., Pittsfield, Mass.
PATTON, PAUL H., Telephone Engineer, Omaha, Neb.
RANDOLPH, ALSTYN F., Assistant to Superintendent of Street Department, Public Service Production Co., Newark, N. J.
SCHWARTZ, BEN, Representative & Sales Engineer, Holophane Glas Co., St. Louis, Mo.
SCOTT, BERNARD W., Assistant to Electrical Engineer, American Woolen Co., Andover, Mass.
SCOVEL, H. W., Engineer, Electrical Division, Illinois Power & Light Corp., Chicago, Ill.
SEARING, HUDSON R., Assistant Electrical Engineer, United Electric Light & Power Co., New York.
SHORT, FRANK A., Electrical Engineer, Safety Electric Products Co., Los Angeles, Calif.
SPARKES, HARRY P., Meter & Transformer Engineer, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.
THOMASON, JOSEPH J., Street Lighting Engineer, Westinghouse Electric & Mfg. Co., St. Louis, Mo.
VEDDER, WILSON Y., Meter Engineer, Brooklyn Edison Co., Brooklyn, N. Y.
VOGAN, FRANK C., Consulting Engineer, Philadelphia, Pa.
WARFIELD, GILMER A., Commercial Engineer of Automatic Substations, Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.
WATERS, WILLIAM A., Electrical Engineer, Manawatu-Oroua Electric Power Board, Palmerston North, New Zealand.
WATT, HAROLD W., Electrical Engineer, Westchester Lighting Co., Yonkers, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings held June 15 and 19, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

HART, PERCY E., Chief Engineer, Toronto Hydroelectric System, Toronto, Ont.
HOUSKEEPER, WILLIAM G., Member of Technical Staff Bell Telephone Laboratories New York.
SKIRROW, JOHN F., Vice-President, Director & Chief Engineer, Postal Telegraph Cable Co., New York.

To Grade of Member

BARROW, CHARLES J., Consulting Engineer, Albany, N. Y.
BLACKWOOD, WILLIAM C., Electrical Engineer, New York & Queens Electric Light & Power Co., Flushing, N. Y.
BULL, EDMUND W., Superintendent of Light & Power, City of Regina, Regina, Sask.
CRAWFORD, PERRY O., Vice-President & Chief Engineer, California Oregon Power Co., Medford, Ore.
DYSON, WALTER, Consulting Electrical Engineer, Tampa, Fla.
FICK, CLARENCE W., Northwest Engineer, General Electric Co., Portland, Ore.
GILLER, FREDERICK S., European Plant Engineer, International Western Electric Co., London, England.
GORDON, CHESTER S., Engineer, Dept. of Development & Research, American Tel. & Tel. Co., New York.
GREVES, GEORGE L., Assistant Professor of Electrical Engineering, University of California, Berkeley, Calif.
HAWKER, CLIFFORD F., Electrical Engineer, E. W. Clark Engineering Corp., Columbus, O.
HORRELL, CHARLES R., Sales Manager, Sangamo Electric Co., Springfield, Ill.

JUDSON, CLARENCE H., Engineer, Outside Plant Methods, Pacific Tel. & Tel. Co., San Francisco, Calif.

LEILICH, FRANK T., Engineer, Consolidated Gas & Electric Co., Baltimore, Md.

MARSHALL, STEWART M., Consulting Engineer, Perin & Marshall, New York.

MERCER, GEORGE G., Assistant Professor of Electrical Engineering, Lafayette College, Easton, Pa.

MURPHY, JOHN J., President & Engineer, Electric Construction & Machinery Co., Rock Island, Ill.

PHILP, GORDON O., Superintendent, Niagara Falls District, Hydro-Electric Power Commission, Niagara Falls, Ont.

SHARLAND, G. A., Chief Electrician, Minnesota By-Product Coke Co., St. Paul, Minn.

TALBOT, HERBERT L., Acting Chief Electrical Engineer, Porto Rico Railway Light & Power Co., San Juan, P. R.

WORCESTER, THOMAS A., Electrical Engineer, General Electric Co., Schenectady, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election for membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before July 31, 1925.

Adler, W. M., The Bronx Gas & Electric Co., Bronx, New York, N. Y.
Anderson, L. I., Commonwealth Edison Co., Chicago, Ill.
Bewlay, W. C., The Electric Products Co., Cleveland, Ohio
Bossemeyer, C. O., Pacific Gas & Electric Co., San Jose, Calif.
Bostwick, J. G., (Member), City Light & Water Plant, Fort Valley, Ga.
Calabrese, G., New York Edison Co., New York, N. Y.
Callahan, C. P., A. G. Mfg. Co., Seattle, Wash.
Canady, J. C., Roth Bros. & Co., Chicago, Ill.
Caricati, V., Draftsman, 1998 Madison Ave., New York, N. Y.
Carlson, A. W., Murrie & Co., New York, N. Y.
Charters, J. S., New York Edison Co., New York, N. Y.
Chutter, G. A., General Electric Co., Schenectady, N. Y.
Cramer, L. P., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Crocker, A. W., U. S. Patent Office, Washington, D. C.
Dawbarn, D. I., A. Reyrolle & Co., Hebburn, Eng. (For mail, Milwaukee, Wis.)
Deardorff, R. W., Pacific Tel. & Tel. Co., San Francisco, Calif.
Dron, R., Elec. Contractor, 403 Madison Ave., Madison, Ill.
Drury, T. J., Star Publishing Co., New York, N. Y.
Erickson, G. L., Bell Telephone Laboratories, Inc., New York, N. Y.
Ethridge, H. P., (Member), Stone & Webster, Inc., Boston, Mass.
Ewaszewski, A. S., Westinghouse Elec. & Mfg. Co., Newark, N. J.
Fields, W. S., American Rolling Mill Co., Ashland, Ky.
Fortington, W. H., Starr Equipment Co., Brooklyn, N. Y.
Garloch, G. L., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Giedd, R. H., Northwestern Public Service Co., Huron, S. Dakota
Gilston, J., (Member), Edwards Elec. Construction Co., New York, N. Y.
Gjerme, R., Ohio Power Co., Canton, Ohio
Gould, M. D., (Member), Westinghouse Elec. & Mfg. Co., Buffalo, N. Y.
Gray, A. W., Pratt Institute, Brooklyn, N. Y.
Griffith, R. T., Bell Telephone Co. of Pa., Pittsburgh, Pa.
Harrington, G. F., Westinghouse Elec. & Mfg. Co. East Pittsburgh, Pa.
Hauterberque, P. J. E., Bell Telephone Laboratories, New York, N. Y.
Heiman, H. C., School of Engineering, Milwaukee, Wis.
Hogan, J. F., Pratt Institute, Brooklyn, N. Y.
Holley, M. E., Philadelphia Electric Co., Philadelphia, Pa.
Hurley, J. F., Brooklyn Edison Co., Brooklyn, N. Y.
Ilaria, A., Hugh L. Cooper & Co., Wilson Dam, Ala.
Jackson, R. H. M., New York Edison Co., New York, N. Y.
Johnson, E. E., General Electric Co., Schenectady, N. Y.
Jones, R. C., Bell Telephone Laboratories, Inc., Chicago, Ill.
Kattens, J. P., 229 10th St., Milwaukee, Wis.
Keith, J. M., Public Service Production Co., Newark, N. J.
Kern, W. M. A., Fuller-Leigh Co., Catasauqua, Pa.
Keyes, D. C., (Member), Grangeville Electric Lt. & Pr. Co., Orofino, Idaho
Kirkwood, G. B., Pacific Electric Mfg. Co., San Francisco, Calif.
Korff, W., Southern California Edison Co., Los Angeles, Calif.
Lagerqvist, G., E. Y. Sayer Engineering Corp. Baltimore, Md.; for mail, Brooklyn, N. Y.
Lang, H. T., Electric Vacuum Cleaner Co., East Cleveland, Ohio
Latting, W. E., Brooklyn Edison Co., Brooklyn, N. Y.
La Vayea, G. L., Jr., 136 W. 44th St., New York, N. Y.
Lefever, P. M., Philadelphia Electric Co., Philadelphia, Pa.
Lyden, J. M., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Mathews, J. R., Kentucky Power Co., Inc., Augusta, Ky.
Maynard, R. D., Public Service Electric & Gas Co., Camden, N. J.
McAnge, W. N., Jr., Inter-Mountain Telephone Co., Bristol, Tenn. (Applicant for re-election)
McKillen, B. A., Hi-Voltage Equipment Co., Cleveland, Ohio
McNally, C., (Member), Electrical Instructor & Engineer, Erie, Pa.
Morecock, E. M., Mechanics Institute, Rochester, N. Y.
Muntz, C. D., (Member), with Geo. B. Sachsenmaier Co., Philadelphia, Pa.
Murphy, W. C., McIntyre Porcupine Mines, Ltd., Schumacher, Ont., Can.
Mutthersbough, W. A., Pennsylvania Power & Light Co., Williamsport, Pa.
Phinney, E. D., U. S. Patent Office, Washington, D. C.
Potts, J. C., New York Telephone Co., New York, N. Y.
Prigohzy, T. A., Freed-Eiseman Radio Corp., Brooklyn, N. Y.
Quinby, E. J., Western Electric Co., New York, N. Y.
Rafsnider, L. B., Cincinnati & Suburban Bell Tel. Co., Cincinnati, Ohio
Rasmussen, O., Commonwealth Edison Co., Chicago, Ill.
Rawlings, M. J., Philadelphia Electric Co. Philadelphia, Pa.
Richards, E. M., (Member), H. O. Swoboda, Inc., Pittsburgh, Pa.
Rider, J. E., Murrie & Co., Brooklyn, N. Y.
Roberson, J. R., Puget Sound Power & Light Co., Everett, Wash.
Rouge, F. K., Electric Products Co., Cleveland, Ohio
Russell, R. E., American Tel. & Tel. Co., Detroit, Mich.
Salgado, A. R., Crocker-Wheeler Co., Ampere, N. J.
Santmyer, G. W., With Frank Sweeney, Connellsville, Pa.
Sellers, O. E., Board of Education, Grace School, Akron, Ohio
Slaman, L., Murdo Electric Co., Murdo, S. Dak.
Sparer, J., Consulting Engineer, 2 Rector St., New York, N. Y.
Stray, G. R., General Electric Co., Schenectady, N. Y.
Swan, F. R., American LaFrance Fire Engine Co., Bloomfield, N. J.
Thompson, A. K., Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Tyler, B. O., Associated Oil Co., Coalinga, Calif.
Van Antwerp, G. S., The Counties Gas & Electric Co., Norristown, Pa.
Walker, R. J., Lieut. U. S. N., U. S. Mississippi, San Francisco, Calif.
Watkins, G. W., General Electric Co., West Lynn, Mass.
Welsome, P. J., Hugh L. Cooper & Co., Inc., Wilson Dam, Florence, Ala.
Young, L. B., Edison Lamp Works of G. E. Co., Atlanta, Ga.
Young, W. W., Jr., New York Edison Co., New York, N. Y.

Total 88

Foreign

Chatelain, M. A., (Fellow), Polytechnic Inst. of Leningrad, Leningrad, Russia
Combi, U. A., Andhra Valley Power Supply Co., Ltd., Bombay Presidency, India
Glock, C. A., Chile Exploration Co., Chuquicamata, Chile, S. A.
Goreleichenko, V. K., (Member), Constr. of Volhov Hydro-Electric Power Plant, Leningrad, Russia
Gumbart, H. E., Standard Oil Co. of New York, Hongkong, S. China
Lindon, C. T., Landis & Gyr Ltd., Zug., Switzerland
Marsh, H. S., U. S. Naval Radio Station, Pearl Harbor, T. H.
Mittell, B., The Gramophone Co., Ltd., Hayes, Middlesex, Eng.
Numata, S., Imperial Gov't. Communication Ministry in Japan, Nakano-machi near Tokyo, Japan
Oliphant, T., Shanghai Municipal Council, Shanghai, China
Takeda, S., Elec. Bureau, Gov't. Railways of Japan, Marunouchi, Tokio, Japan
Zelentsoff, M. E., (Fellow), Electrotechnical Inst., Leningrad, Russia

Total 12

STUDENTS ENROLLED JUNE 25, 1925

Aleman, Eugenio D., Escuela de Ingenieros Mecanicos Electricistas
Armstrong, William C., Worcester Polytechnic Institute
Beaman, Asahel E., University of Toronto
Benedict, Reginald R., University of Wisconsin
Beck, Lester E., Pennsylvania State College
Best, George R., University of Colorado
Blair, Marshall L., University of Idaho
Brockman, Harry D., University of Iowa
Brown, Hart, Rice Institute
Browne, Kenneth, University of Colorado
Burton, Charles G., Jr., Washington & Lee University
Camacho G., Leandro, Escuela de Ingenieros Mecanicos Electricistas
Campos, Emilio G., Escuela de Ingenieros Mecanicos Electricistas
Cantley, J. Vernon, Northeastern University
Chagoyan, Horacio, Escuela de Ingenieros Mecanicos Electricistas
Chrestenson, Paul E., University of Iowa
Christensen, Andrew T., Rhode Island State College

Corliss, Francis M., Mass. Institute of Technology
Cox, Glen, University of Iowa
Cummins, Edward L., University of Iowa
Cyr, Howard A., Mass. Institute of Technology
Dusinberre, Clayton T., Engineering School of Milwaukee
Fischer, Frank P., Washington & Lee University
Gardner, Jack F., Oregon Agricultural College
Genske, Cecil A., Engineering School of Milwaukee
Gettelman, Arthur F., University of Wisconsin
Gideon, Willard I., Mass. Institute of Technology
Gilman, Wilbert M., Mass. Institute of Technology
Hamilton, Kenneth H., Stanford University
Isom, Leo M., Brown University
Jager, Robert J., Alabama Polytechnic Institute
Keefe, Oscar A., Mass. Institute of Technology
Kempf, Math. B., Marquette University
Kinser, Joe H., Rice Institute
Knapp, Floyd H., Rensselaer Polytechnic Institute
Kurz, Gustavo, Escuela de Ingenieros Mecanicos Electricistas
Lee, Samuel M., Engineering School of Milwaukee
Lowe, Frank T., Pennsylvania State College
Marshall, Donald E., University of Iowa
Martin, Ronald J., Mass. Institute of Technology
Mason, Charlton M., University of Cincinnati
McAuliffe, John J., Worcester Polytechnic Institute
Monti, Louis P., Brown University
Murphy, Henry T., University of Toronto
Ness, Theodore N., Iowa State College
Nophsker, Robert J., Pennsylvania State College
Ottenheimer, Joseph L., University of Colorado
Paullin, Charles S., Georgia School of Technology
Pollard, Jack C., Rice Institute
Porter, Harold M., Kansas State Agricultural College
Prentiss, Guernsey D., Columbia University
Reed, Edgar W., Pennsylvania State College
Reihman, Earl F., University of Iowa
Reyna N., Rodolfo, Escuela de Ingenieros Mecanicos Electricistas
Rice, Hamilton S., Brown University
Rushton, Allen, Washington & Lee University
Schuchert, Joseph S., Carnegie Institute of Technology
Shelton, Thomas M., University of Colorado
Shindler, George F., University of Southern California
Sjoblom, Theodore, University of Utah
Sperr, Walter H., Stevens Institute of Technology
Sprague, Albert T., Jr., Harvard University
Taylor, Bayden P., Rhode Island State College
Thomas, Cleo W., University of Wisconsin
Thompson, Russell E., California Institute of Technology
Tomlinson, I. Stanley, Pennsylvania State College
Traber, John P. Georgia School of Technology
Ulanetsky, Herman, Newark Technical School
Volkmer, Theodore F., University of Iowa
Warrington, Peirce E., Stanford University
Werner, William L., Pennsylvania State College
Wood, Charles M., Washington & Lee University
Yood, Lewis D., Mass. Institute of Technology
Zara, Frank J., University of Iowa
Total 74

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Charles le Maistre, 28 Victoria St., London, S. W., 1, England
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E, France
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Guido Semenza, 39 Via Monte Napoleone, Milan, Italy
Eiji Aoyagi, Kyoto Imperial University, Kyoto, Japan
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W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa

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(A list of the personnel of Institute committees may be found in the June issue of the JOURNAL.)

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PRODUCTION AND APPLICATION OF LIGHT, G. H. Stickney
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GENERAL POWER APPLICATIONS, A. E. Waller
POWER GENERATION, Vern E. Alden
POWER TRANSMISSION AND DISTRIBUTION, Percy H. Thomas
PROTECTIVE DEVICES, H. R. Woodrow
RESEARCH, John B. Whitehead

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(The Institute is represented on the following bodies; the names of the representatives may be found in the June issue of the JOURNAL.)
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AMERICAN COMMITTEE ON ELECTROLYSIS
AMERICAN ENGINEERING COUNCIL
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A. I. E. E. SECTIONS AND BRANCHES

See the June issue for the latest published list. The Institute now has 49 Sections and 82 Branches.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies

Recording Thermometers.—Bulletin 1303, 56 pp. Describes gas filled thermometers for recording temperature between 60° below zero and 1000° F. The Bristol Company, Waterbury, Conn.

Megohmers. Bulletin 130, 8 pp. Describes Model "D" Standco megohmers for insulation resistance measurements. Herman H. Sticht & Company, 15 Park Row, New York.

Insulating Varnishes.—Handbook. A complete treatise on insulating varnishes and compounds and their applications. The Sherwin-Williams Company, 601 Canal Road, Cleveland, O.

Capacitance Measurements.—Catalog 10, 48 pp. Describes apparatus for capacitance and inductance measurements and magnetic testing. The Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Pa.

Control Apparatus.—Bulletin 108, 28 pp., "Newspaper Printing Press Control." Describes the Monitor push button control for printing machinery. Monitor Controller Company, Baltimore, Md.

Terminal Blocks.—Bulletin H-2, 16 pp. Describes "Controlead" terminal blocks designed for use in simplifying methods of control wiring. Illustrations are included showing typical installations. Burke Electric Company, Erie, Pa.

Generator Air Cooling Systems.—Bulletin A-69. Describes "Spraco" recirculated and open air systems for generator cooling. Air washers and coolers are also treated in this bulletin. Spray Engineering Company, 60 High Street, Boston, Mass.

Standardized Substations.—Bulletin 12. Describes a new line of standardized steel tower outdoor substations intended for installation by utilities serving, or customers buying power from high tension distribution lines. Delta-Star Electric Company, 2433 Fulton St., Chicago, Ill.

Electrical Testing.—Bulletin, 96 pp., "Electrical Testing in Industry." This is a comprehensive survey of testing practise, compiled by E. S. Lincoln, consulting engineer, in cooperation with the engineering staff of the Weston Electrical Instrument Company, 48 Weston Avenue, Newark, N. J.

Water Cooling Systems.—Bulletin 392, 16 pp. Describes the "Spraco" system for cooling condensing and circulating water. A number of typical installations are listed and illustrated in the bulletin. Spray Engineering Company, 60 High Street, Boston, Mass.

Wiring Symbols.—A chart attractively printed on cardboard for wall hanging, showing the standard symbols for wiring plans as recommended by the American Engineering Standards, the A. I. E. E., American Institute of Architects, and the Association of Electragists, is being issued by the A. A. Wire Company, 110 East 42nd Street, New York.

Arc Welding Generator.—Bulletin 436, 4 pp. Describes the Hansen arc welder. Among the features of the machine is the lack of external stabilizing devices for striking and maintaining the arc, thereby avoiding the detrimental effects of such stabilizers. At present two ratings of Hansen welders are being built. The small machine has a voltage range from 60 to 350 amperes and the larger machine has a range from 90 to 400 amperes. Northwestern Manufacturing Company, Milwaukee, Wis.

Bushings.—Bulletin H-1, 44 pp. Describes round and rectangular wall and floor entrance bushings, made in all lengths up to 34 in. for all sizes of copper tubing, cable and flat bar conductors. Such bushings are made of "Burkelect," a composition embodying electrical and mechanical qualities which makes it exceptionally well suited for use as a high voltage insulation medium. Burke Electric Company, Erie, Pa.

Valve Control.—Bulletin 103-29 B, 12 pp. Describes Cory-Recony standardized unit control for motor operation of valves. Among the features treated are remote control, separate power panel in which all circuits are opened and closed, electrical braking permitting seating with full power, easily set limit switch with positive adjustment, position and manual declutch signal lights at the control station and any angle installation. The units are made in sizes to operate remotely, valves from 2 to 60 inches under varying pressure and temperature conditions. Chas. Cory & Son, Inc., 183 Varick St., New York.

NOTES OF THE INDUSTRY

The Trico Fuse Manufacturing Company, Milwaukee, Wis., has removed its Chicago districts sales office to 1742 Monadnock Block, Chicago.

The Ward Leonard Electric Company, Mt. Vernon, N. Y., manufacturers of resistor units and control apparatus, announce the appointment of Warburton, Franki Ltd., Sydney and Melbourne, Australia, as their selling agents in that territory.

The Creaghead Engineering Company, 325 Main Street, Cincinnati, O., announces the opening of a new department for the manufacture of highly improved safety switches. These devices will be manufactured and sold under the name of the Creaghead Red Seal Safety Switch. The first division of the line will be a complete set of meter entrance switches, to be followed by industrial and motor-starting switches.

The General Electric Company has concluded an agreement with the Societa Italiana Pirelli of Milan, Italy, for working the Pirelli patents on paper insulated cables, joints and fittings, together with the use of manufacturing and research information in regard to this type of cable, in the United States. This agreement will render available to the electrical public utilities of the United States the Pirelli Company's special development in very high tension cable, and the General Electric Company's experience in manufacture, engineering and research, in the application of such high tension cables to American practise.

Double Polyphase Meter.—The Sangamo Electric Company, Springfield Ill., has developed a double polyphase switchboard type watthour meter originally designed to enable a prominent central station to measure the interchange of power in a transmission circuit where the available switchboard space was limited. As the double polyphase meter consists of two vertical meters on a single-phase, it is readily adaptable to measurement of power in separate circuits, or to the determination of the energy and the reactive components in a single circuit.

Portable Instruments.—The Westinghouse Electric & Manufacturing Company has introduced a new set of portable indicating instruments that may be used for both alternating and direct current. The complete set, including an ammeter, voltmeter and single phase wattmeter, which may be carried in a suitcase, should be useful for those who do research or experimental work in electricity or related sciences, because the instruments are compact, light, and give reliable readings.

Electric Drive Supersedes Steam in Steel Mill.—One of the most radical change-overs from steam to electric drive in the history of the steel industry is to be made by the Colorado Fuel & Iron Company at its Minnequa Works, Pueblo, Colorado. This plant, the largest steel mill in the west, recently completed arrangements for the adoption of electric power, generated on the premises, for use in its rolling mills. The mills are, at present, engine-driven, using low pressure steam obtained from a hand-fired boiler plant. This plant will be superseded by a complete new power house, using powdered fuel and waste gas fired boilers which will provide steam at 300 lb. pressure and 180° F. superheat. Complete electrical equipment will be furnished by the General Electric Company and will include two 10,000-kilowatt turbine generators as the prime movers, to furnish alternating current to the main power lines at 6600 volts. Motors of 300 to 3000 h. p. capacity will drive the mills.